UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

SOIL REPORT NO. 9

LAKE COUNTY SOILS

By CYRIL G. HOPKINS, J. G. MOSIER,
E. VAN ALSTINE, and F. W. GARRETT

URBANA, ILLINOIS, APRIL, 1915

INTRODUCTORY NOTE

About two-thirds of Illinois lies in the corn belt, where most of the prairie lands are black or dark brown in color. In the southern third of the state, the prairie soils are largely of a gray color. This region is better known as the wheat belt, altho wheat is often grown in the corn belt and corn is also a common crop in the wheat belt.

Moultrie county, representing the corn belt; Clay county, which is fairly representative of the wheat belt; and Hardin county, which is taken to represent the unglaciated area of the extreme southern part of the state, were selected for the first Illinois Soil Reports by counties. While these three county soil reports were sent to the Station's entire mailing list within the state, subsequent reports are sent only to those on the mailing list who are residents of the county concerned, and to any one else upon request.

Each county report is intended to be as nearly complete in itself as it is practicable to make it, and, even at the expense of some repetition, each will contain a general discussion of important fundamental principles in order to help the farmer and landowner understand the meaning of the soil fertility invoice for the lands in which he is interested. In Soil Report No. 1, "Clay County Soils," this discussion serves in part as an introduction, while in this and other reports, it will be found in the Appendix; but if necessary it should be read and studied in advance of the report proper.

SOIL CONDITIONS IN NORTHEASTERN ILLINOIS

(Statement Supplementing the Soil Reports for the Counties Listed Below)

The soil maps of the counties in northeastern Illinois which were made from 23 to 45 years ago do not show the character of the glacial till underlying the soils in this region. This fact makes it necessary to interpret these maps in the light of more recent knowledge, since the agricultural value of the soils in this part of the state often is determined by the character of the underlying material.

The counties having soil maps which are defective in this respect are Champaign, Cook (unpublished), DuPage, Grundy, Kane, Kankakee, Lake, LaSalle, McHenry, McLean, Piatt, Will, and Woodford.

In addition to the counties listed, the following counties now have soil maps showing the areas where unfavorable underlying glacial till is present: Ford, Iroquois, Kendall, Livingston, Marshall, Putnam, and Vermilion.

The glacial tills in the northeastern part of Illinois vary from highly plastic, very slowly permeable material to loose, sandy, gravelly material which is porous and drouthy. The following tabulation shows the tills ranging in permeability to water from very slowly permeable to optimum or moderate permeability, but does not show the sandy, gravelly tills which occur less extensively than the slowly permeable tills. Only the dark-colored or prairie soils are listed, as they are more extensive than the light-colored or timber soils in all counties in this region except Lake and McHenry.

Silty clay till - Swygert-Bryce soils - slowly permeable
Silty clay loam till - Elliott-Ashkum soils - moderately slowly permeable
Loam till - Saybrook-Lisbon soils - optimum permeability

On all soil maps published prior to 1930 the above-listed soils were for the most part shown as Brown Silt Loam and Black Clay Loam. The agricultural significance of the separations now being made is indicated by the following yields of hybrid corn on farms under good management for the period 1937 to 1944.

Clarence-Rowe	-	average of	3	farms	-	51 bushels an acre
Swygert-Bryce	-	" "	12	"	-	60 bushels an acre
Elliott-Ashkum	-	" "	20	"	-	64 bushels an acre
Saybrook-Lisbon	-	" "	20	"	-	76 bushels an acre

Further information about soil conditions in northeastern Illinois and in other parts of the state may be secured from the county farm advisers and from the Soil Survey, Department of Agronomy, Urbana.

Department of Agronomy
University of Illinois
Agricultural Experiment Station

1949

AG1286

LAKE COUNTY SOILS

By Cyril G. Hopkins, J. G. Mosier, E. Van Alstine, and F. W. Garrett

Lake county is located in the northeast corner of Illinois in the late Wisconsin glaciation, and is covered with a deposit of material made by the Lake Michigan glacier during its two stages. The topography of the county, tho quite rolling in many parts, is due almost entirely to the very irregular deposition of material by this glacier. Two distinct morainal areas occur. The one known as the Lake Border morainic system occupies the eastern part of the county and extends southward in the form of two low ridges, one near the lake and another just east of the Des Plaines river; the other, the Valparaiso morainic system, occupies the western part of the county. The latter reaches an altitude of about 300 feet above Lake Michigan. These morainic areas are marked by large numbers of kettle-holes, or basin-like depressions, that in the most rolling parts sometimes have a depth of 75 feet. Numerous lakes are found in the Valparaiso morainic system.

The drift deposited by the Lake Michigan glacier over the county has a minimum depth of probably 150 feet, while the thicker deposits are between 300 and 400 feet. Leverett, in Monograph 38 of the United States Geological Survey, states that the deposit of drift averages more than 200 feet in thickness over the county. Borings indicate the presence of still older glacial drift beneath that of the late Wisconsin.

Physiography

Lake county is divided into two distinct drainage systems—one sloping into Lake Michigan and comprizing probably not more than one-fifteenth of the total area of the county, and a second, drained by the Des Plaines and the Fox rivers, into the Illinois. The large number of lakes and swamps in this county indicate very late drainage systems, so late that practically all of the lowland is occupied either by lakes or by swamps. The streams have not had time to form valleys sufficiently deep for draining these low areas. There are about fifty lakes in the county large enough to be shown on the soil map, many of which are surrounded, or nearly so, by swamps containing deposits of peat.

The altitudes of some places in the county above sea level are as follows: Antioch, 770 feet; Aptakisic, 682; Diamond Lake, 760; Fox Lake, 745; Gilmer, 810; Gray's Lake, 799; Gurnee, 677; Highland Park, 691; Lake Bluff, 683; Lake Villa, 796; Lake Zurich, 873; Leithton, 723; Libertyville, 670; Loon Lake, 783; Prairie View, 694; Rodont, 676; Russell, 677; Volo, 890; Wadsworth, 673; War-

renton, 710; Waukegan (C. & N. W.), 596. A bench mark on the east entrance of the courthouse at Waukegan is 668.4 feet. The mean altitude of the water of Lake Michigan is 581 feet above sea level.

SOIL MATERIAL AND SOIL TYPES

The Lake Michigan glacier left a deposit of boulder clay (a mixture of boulders, gravel, sand, silt, and clay), which has been transformed into soil in some places; but the larger part of the county subsequently received a shallow deposit of 12 to 40 inches of loessial material formed from the fine rock flour produced by the grinding action of the glacier. This has been reworked by the wind and water and now covers the level and less rolling areas to an average depth of 16 to 20 inches. Beneath this is often found a stratum a few inches in thickness which contains a great many gravel, indicating the washing out of the fine material before the loess was deposited. From Waukegan to the state line a deposit has been formed by Lake Chicago which consists of a series of sand ridges only a few rods apart that have very little argricultural use. Between these ridges peat deposits are frequently found.

TABLE 1.—SOIL TYPES OF LAKE COUNTY

Soil type No.	Name of type	Area in square miles	Area in acres	Percent of total area
	(a) Upland Prairie Soils (page 23)			
1026, 1226	Brown silt loam	137.50	88 001	28.48
1060, 1260	Brown sandy loam	2.88	1 844	.60
	(b) Upland Timber Soils (page 25)			
1034, 1234	Yellow-gray silt loam	196.01	125 447	40.59
1035, 1235	Yellow silt loam	38.50	24 639	7.98
1064	Yellow-gray sandy loam	.76	488	.16
1064.4	Yellow-gray sandy loam on gravel	1.48	944	.30
1081, 1281	Dune sand	1.47	938	.30
1090, 1290	Gravelly loam	.96	611	.20
	(c) Terrace Soils (page 30)			
1527	Brown silt loam over gravel	1.85	1 184	.38
1564.4	Yellow-gray sandy loam on gravel	2.25	1 440	.47
1560.4	Brown sandy loam on gravel	2.40	1 539	.50
1590.4	Gravelly loam on gravel	.28	179	.06
	(d) Swamp and Bottom-Land Soils (page 32)			
1401	Deep peat	38.10	24 382	7.89
1402	Medium peat on clay	1.00	640	.21
1402.2	Medium peat on sand	.44	284	.09
1403	Shallow peat on clay	.58	371	.12
1410	Peaty loam	2.35	1 504	.49
1450	Black mixed loam	19.72	12 622	4.09
1454	Mixed loam (bottom land)	8.51	5 446	1.76
1482	Beach sand (mixed sand and peat)	7.79	4 988	1.61
	(e) Miscellaneous (page 38)			
	Lakes	17.99	11 512	3.72
	Total	482.82	309 003	100.00

The soils of Lake county are divided into the following classes:

(1) Upland prairie soils, usually rich in organic matter. These were covered originally with prairie grasses, the partially decayed roots of which have been the source of the organic matter. The flat, poorly drained areas contain the highest amounts of organic matter, owing to the more luxuriant growth of grasses there and the better chance for their preservation by the excessive moisture in the soil.

(2) Upland timber soils, including nearly all upland areas that were formerly covered with forests. These soils contain much less organic matter than the soils of the prairies because the large roots of dead trees and the surface accumulations of leaves, twigs, and fallen trees were burned by forest fires, or suffered almost complete decay, instead of being incorporated with the soil.

(3) Terrace soils, which include bench lands, or second bottom lands, that were formed at the time of the melting of the glacier, when the valleys were flooded and the streams overloaded with coarse sediment. Deposits of gravel were formed which later have been cut thru in part by the streams during their ordinary stages. These benches form soil types that are usually underlain by gravel or sand.

(4) Swamp and bottom-land soils, which include the overflow lands or flood plains along the streams, the swamps around some of the lakes, the poorly drained lowlands, and the area of sand beaches deposited by Lake Chicago.

Table 1 shows the area of each type of soil in Lake county in square miles and in acres, and its percentage of the total area. It will be noted that the yellow-gray silt loam, or undulating timber land, occupies the larger part of the county. The accompanying map shows the location and boundary lines of every type of soil in the county, even down to areas of a few acres.

THE INVOICE AND INCREASE OF FERTILITY IN LAKE COUNTY SOILS

SOIL ANALYSIS

In order to avoid confusion in applying in a practical way the technical information contained in this report, the results are given in the most simplified form. The composition reported for a given soil type is, as a rule, the average of many analyses, which, like most things in nature, show more or less variation; but for all practical purposes the average is most trustworthy and sufficient. (See Bulletin 123, which reports the general soil survey of the state, together with many hundred individual analyses of soil samples representing twenty-five of the most important and most extensive soil types in the state.)

The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but, as explained in the Appendix, the rate of liberation is governed by many factors. Also, as there stated, probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even tho plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the

poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that the productive power of normal soil in humid sections depends upon the stock of plant food contained in the soil and upon the rate at which it is liberated.

The fact may be repeated, too, that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all plants, only one (hydrogen) from water, while seven are secured from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes) in case the amount liberated from the soil is insufficient. But even the leguminous plants (which include the clovers, peas, beans, alfalfa, and vetches), in common with other agricultural plants, secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron, and sulfur) and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Table A in the Appendix shows the requirements of large crops for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally from natural sources in sufficient abundance, compared with the amounts needed by plants, so that they are never known to limit the yield of common farm crops.)

In Table 2 are reported the amounts of organic carbon (the best measure of the organic matter) and the total amounts of the five important elements of plant food contained in 2 million pounds of the surface soil of each type,—the plowed soil of an acre about 6⅔ inches deep. In addition, the table shows the amount of limestone present, if any, or the soil acidity as measured by the amount of limestone required to neutralize the acidity existing in the soil.

The soil to the depth indicated includes at least as much as is ordinarily turned with the plow, and represents that part with which the farm manure, limestone, phosphate, or other fertilizer applied in soil improvement is incorporated. It is the soil stratum that must be depended upon in large part to furnish the necessary plant food for the production of crops, as will be seen from the information given in the Appendix. Even a rich subsoil has little or no value if it lies beneath a worn-out surface, for the weak, shallow-rooted plants will be unable to reach the supply of plant food in the subsoil. If, however, the fertility of the surface soil is maintained at a high point, then the plants, with a vigorous start from the rich surface soil, can draw upon the subsurface and subsoil for a greater supply of plant food.

By easy computation it will be found that the most common prairie soil of Lake county does not contain more than enough total nitrogen in the plowed soil for the production of maximum crops for fifteen rotations (60 years), while the still more extensive upland timber soil (yellow-gray silt loam) contains only about one-third as much nitrogen as the prairie land, or sufficient for only eighteen 100-bushel crops of corn, grain, and stalks.

With respect to phosphorus, the condition differs only in degree, half the soil area of the county containing no more of that element than would be re-

quired for ten crop rotations if such yields were secured as are suggested in Table A of the Appendix. It will be seen from the same table that in the case of the cereals about three-fourths of the phosphorus taken from the soil is deposited in the grain, while only one-fourth remains in the straw or stalks.

On the other hand, the potassium in the most common soil type is sufficient for 36 centuries if only the grain is sold, or for 560 years even if the total crops should be removed and nothing returned. The corresponding figures are about 2,300 and 540 years for magnesium, and about 7,800 and 200 years for calcium. Thus, when measured by the actual crop requirements for plant food, potassium is no more limited than magnesium and calcium; and as explained in the Appendix, with magnesium, and more especially with calcium, we must also consider the fact that loss by leaching is far greater than by cropping.

These general statements relating to the total quantities of plant food in the plowed soil of the most prevalent type in the county certainly emphasize the fact that the supplies of some of these necessary elements of fertility are extremely limited when measured by the needs of large crop yields for even one or two generations of people.

TABLE 2.—FERTILITY IN THE SOILS OF LAKE COUNTY, ILLINOIS

Average pounds per acre in two million pounds of surface soil (about 0 to 6⅔ inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity
	Upland Prairie Soils								
1226	Brown silt loam........	89 950	7 490	1 430	46 930	12 680	13 300		50
1060	Brown sandy loam......	8 300	640	420	25 200	2 680	5 020		40
	Upland Timber Soils								
1234	Yellow-gray silt loam...	32 220	2 720	750	46 300	9 210	7 820		40
1035	Yellow silt loam........	20 900	1 880	720	58 300	12 380	6 270		30
1064	Yellow-gray sandy loam.	18 000	1 720	800	34 280	5 480	7 220		20
1064.4	Yellow-gray sandy loam on gravel	20 660	1 520	920	34 580	5 080	10 460		40
1281	Dune sand	26 000	1 860	780	23 960	4 920	8 760	12 720	140
1090	Gravelly loam	33 580	2 760	1 000	30 920	11 960	16 000		
	Terrace Soils								
1527	Brown silt loam over gravel	62 340	5 180	1 340	36 340	7 460	8 900		60
1564.4	Yellow-gray sandy loam on gravel	30 820	2 680	1 120	38 600	7 480	9 540		40
1560.4	Brown sandy loam on gravel	28 280	2 420	780	37 660	7 680	10 680		20
1590.4	Gravelly loam on gravel	37 380	3 240	1 420	33 380	8 960	9 160	1 020	
	Swamp and Bottom-Land Soils								
1401	Deep peat (slightly decomposed moss)	445 080	7 990	670	6 120	3 360	2 850		8 380
1401	Deep peat, normal phase	398 040	32 570	1 540	3 900	6 260	24 970		140
1402	Medium peat on clay...	206 230	17 380	1 240	16 450	9 140	18 450		50
1402.2	Medium peat on sand...	271 560	18 450	1 080	12 420	8 080	18 860		80
1403	Shallow peat on clay...	380 800	27 420	1 110	6 410	6 310	28 780		290
1410	Peaty loam	334 170	31 650	2 300	18 540	13 410	40 050	Often	
1450	Black mixed loam......	164 480	13 640	1 740	35 000	14 140	24 760	16 080	
1454	Mixed loam (bottom land)	89 440	8 190	1 490	34 690	45 460	91 180	301 130	
1482	Beach sand	5 420	420	660	16 100	9 620	14 320		20

The variation among the different types of soil in Lake county with respect to their content of important plant-food elements is also very marked. Thus the yellow silt loam contains in 2 million pounds of surface soil sufficient total nitrogen for 12 "maximum" crops of corn, sufficient phosphorus for 31 crops, and potassium for 800 such crops; while the deep peat contains in 1 million pounds of surface soil, nitrogen for 217, phosphorus for 67, and potassium for only 53 corn crops of 100 bushels each. Each of these soil types covers about 8 percent of the county. More than 90 percent of the soils of the county contain no limestone in the surface or subsurface to a depth of 20 inches, altho the presence of limestone is beneficial for most crops, especially for the valuable biennial and perennial legumes, such as the clovers and alfalfa.

With an inexhaustible supply of nitrogen in the air, and with 46,000 pounds of potassium in the most common timber soil, the economic loss in farming such land with some acidity and with only 750 pounds of total phosphorus in the plowed soil can be appreciated only by the man who fully realizes that in less than one generation the crop yields could be doubled by the proper use of limestone and phosphorus in rational farm systems, without change of seed or season and with very little more work than is now devoted to the fields. Fortunately, some definite field experiments have already been conducted on this most extensive type of soil in Lake county.

RESULTS OF EXPERIMENTS ON ANTIOCH FIELD

Table 3 shows in detail thirteen years' results secured from the Antioch soil experiment field located on the farm of Mr. D. M. White, on the yellow-gray silt loam of the late Wisconsin glaciation. Table 4 is a financial summary of these results.

The Antioch field was started in order to learn as quickly as possible what effect would be produced by the addition to this type of soil, of nitrogen, phosphorus, and potassium, singly and in combination. These elements were all added in commercial form until 1911, after which the use of commercial nitrogen was discontinued and crop residues were substituted in its place. (See report of Urbana field for further explanations, page 9.) Only a small amount of lime was applied at the beginning, in harmony with the teaching which was common at that time; furthermore, Plot 101 proved to be abnormal, so that no conclusions can be drawn regarding the effect of lime. In order to ascertain the effect produced by additions of the different elements singly, Plot 102 must be regarded as the check plot. Three other comparisons are also possible to determine the effect of each element under different conditions.

As an average of 40 tests (4 each year for ten years), liberal applications of commercial nitrogen produced a slight decrease in crop values; but as an average of thirteen years each dollar invested in phosphorus paid back $2.54 (Plot 104), while potassium applied in addition to phosphorus (Plot 108) produced no increase, the crops being valued at the lower prices used in the tabular statement. Thus, while the detailed data show great variation, owing both to some irregularity of soil and to some very abnormal seasons, with three almost complete crop failures (1904, 1907, and 1910), yet the general summary strongly confirms the analytical data in showing the need of applying phosphorus and

TABLE 3.—CROP YIELDS IN SOIL EXPERIMENTS, ANTIOCH FIELD

Yellow-gray silt loam, undulating timberland; late Wisconsin glaciation		Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910
Plot	Soil treatment applied[1]	Bushels or tons per acre								
101	None	44.8	36.6	17.8	18.5	35.9	12.4	65.6	12.2	5.2
102	Lime	45.1	38.9	12.8	10.3	31.5	9.5	61.6	11.7	3.0
103	Lime, nitrogen	46.3	40.8	2.8	17.8	37.8	6.4	60.3	13.0	1.4
104	Lime, phosphorus	50.1	53.6	12.5	35.8	57.4	13.4	70.9	23.3	6.8
105	Lime, potassium	48.2	50.2	9.7	21.7	34.9	12.9	62.5	13.5	4.6
106	Lime, nitrogen, phosphorus	56.6	62.7	15.9	15.2	59.3	20.9	49.1	33.8	6.0
107	Lime, nitrogen, potassium	52.1	54.9	10.3	11.8	39.0	11.1	52.6	21.0	1.6
108	Lime, phosphorus, potassium	60.7	66.0	19.7	28.7	59.1	18.5	59.4	26.2	3.2
109	Lime, nitrogen, phosphorus, potassium	61.2	69.1	31.9	18.0	65.9	31.4	51.9	30.5	3.0
110	Nitrogen, phosphorus, potassium	59.7	71.8	37.2	16.3	66.3	28.8	55.9	34.5	4.0
		Increase: Bushels or Tons per Acre								
For nitrogen		1.2	1.9	-10.0	7.5	6.3	-3.1	-1.3	1.3	-1.6
For phosphorus		5.0	14.7	-.3	25.5	25.9	3.9	9.3	11.6	3.8
For potassium		3.1	11.3	-3.1	11.4	3.4	3.4	.9	1.8	1.6
For nitrogen, phosphorus over phosphorus		6.5	9.1	3.4	-20.6	1.9	7.5	-21.8	10.5	-.8
For phosphorus, nitrogen over nitrogen		10.3	21.9	13.1	-2.6	21.5	14.5	11.2	20.8	4.6
For postassium, nitrogen, phosphorus over nitrogen, phosphorus		4.6	6.4	16.0	2.8	6.6	10.5	2.8	3.3	3.0

[1]Crop residues in place of commercial nitrogen after 1911.
[2]Figures in parentheses indicate bushels of seed; the others, tons of hay.
[3]No seed produced: clover plowed under on these plots.

the profit from its use, and the loss in adding potassium. In most cases commercial nitrogen damaged the small grains by causing the crop to lodge; but in those years when a corn yield of 40 bushels or more was secured by the application of phosphorus either alone or with potassium, then the addition of nitrogen produced an increase.

TABLE 4.—VALUE OF CROPS PER ACRE IN THIRTEEN YEARS, ANTIOCH FIELD

Plot	Soil treatment applied	Total value of thirteen crops	
		Lower prices[1]	Higher prices[2]
101	None	$135.12	$193.03
102	Lime	119.74	171.06
103	Lime, nitrogen	124.70	178.15
104	Lime, phosphorus	202.20	288.85
105	Lime, potassium	138.88	198.40
106	Lime, nitrogen, phosphorus	179.41	256.31
107	Lime, nitrogen, potassium	133.54	190.77
108	Lime, phosphorus, potassium	201.35	287.65
109	Lime, nitrogen, phosphorus, potassium	191.22	273.18
110	Nitrogen, phosphorus, potassium	196.32	280.88
	Value of Increase per Acre in Thirteen Years		
For nitrogen		$ 4.96	$ 7.09
For phosphorus		82.46	117.79
For *nitrogen* and phosphorus over phosphorus		–22.79	–32.54
For *phosphorus* and nitrogen over nitrogen		54.71	78.16
For *potassium,* nitrogen, and phosphorus over nitrogen and phosphorus		11.81	16.87

[1]Wheat at 70 cents a bushel, corn at 35 cents, oats at 28 cents, hay at $7 a ton.
[2]Wheat at $1 a bushel, corn at 50 cents, oats at 40 cents, hay at $10 a ton.

PLATE 1.—CLOVER IN 1913 ON ANTIOCH FIELD
LIME APPLIED AND RESIDUES PLOWED UNDER

From a comparison of the results from the Urbana, Sibley, and Bloomington fields (see following pages), we must conclude that better yields are to be secured by providing nitrogen by means of farm manure or legume crops grown in the rotation than by the use of commercial nitrogen, which is evidently too readily available, causing too rapid growth and consequent weakness of straw; and of course the atmosphere is the most economic source of nitrogen where that element is needed for soil improvement in general farming. (See Appendix for detailed discussion of "Permanent Soil Improvement."

RESULTS OF FIELD EXPERIMENTS AT URBANA

No soil experiment field has been conducted on the brown silt loam of the late Wisconsin glaciation, but we may well consider the results from long continued experiments on similar soil in the early Wisconsin glaciation, as at Urbana in Champaign county, at Sibley in Ford county, and at Bloomington in McLean county. (Long-cultivated fields of brown silt loam in the late Wisconsin glaciation are sometimes found to contain no more phosphorus or nitrogen than the average in the brown silt loam of the early Wisconsin.)

A three-year rotation of corn, oats, and clover was begun on the North Farm at the University of Illinois in 1902, on three fields of typical brown silt loam prairie land which, after twenty years or more of pasturing, had grown corn in 1895, 1896, and 1897 (when careful records were kept of the yields produced), and had then been cropped with clover and grass on one field (Series 100), oats on another (Series 200), and oats, cowpeas, and corn on the third field (Series 300) until 1901.

PLATE 2.—CLOVER IN 1913 ON ANTIOCH FIELD
LIME AND PHOSPHORUS APPLIED

From 1902 to 1910 the three-year rotation (with cowpeas in place of clover in 1902) was followed; the average yields are recorded in Table 5. A small crop of cowpeas in 1902 and a partial crop of clover in 1904 constituted all the hay harvested during the first rotation, mammoth clover grown in 1903 having lodged so that it was plowed under. (The yields were taken by carefully weighing the clover from small representative areas, but while the differences were thus ascertained and properly credited temporarily to the different soil treatments, they must ultimately reappear in subsequent crop yields, and consequently the 1903 clover crop is omitted from Table 5 in computing yields and values.) The average yields given represent one-third of the two small crops.

From 1902 to 1907 legume cover crops (Le), such as cowpeas and clover, were seeded in the corn at the last cultivation on Plots 2, 4, 6, and 8, but the growth was small and the effect, if any, was to decrease the returns from the regular crops. Since 1907 crop residues (R) have been returned to those plots. These consist of the stalks of corn, the straw of small grains, and all legumes except alfalfa hay and the seed of clover and soybeans.

On Plots 3, 5, 7, and 9, manure (M) was applied for corn at the rate of 6 tons per acre during the second rotation, and subsequently as many tons of manure have been applied as there were tons of air-dry produce harvested from the corresponding plots.

Lime (L) was applied on Plots 4 to 10 at the rate per acre of 250 pounds of air-slaked lime in 1902 and 600 pounds of limestone in 1903. Subsequently 2 tons per acre of limestone was applied to these plots on Series 100 in 1911, on Series 200 in 1912, on Series 300 in 1913, and on Series 400 in 1914; also 2½ tons per acre on Series 500 in 1911, two more fields having been brought into rotation, as explained below.

Phosphorus (P) has been applied on Plots 6 to 9 at the rate of 25 pounds per acre per annum in 200 pounds of steamed bone meal; but beginning with 1908, one half of each phosphorus plot has received 600 pounds of rock phosphate in place of the 200 pounds of bone meal, the usual practice being to apply and plow under at one time all phosphorus and potassium required for the rotation.

Potassium (K=kalium) has been applied on Plots 8 and 9 at the yearly rate of 42 pounds per acre in 100 pounds of potassium sulfate, regularly in connection with the bone meal and rock phosphate.

On Plot 10 about five times as much manure and phosphorus are applied as on the other plots, but this "extra heavy" treatment was not begun until 1906, only the usual lime, phosphorus, and potassium having been applied in previous years. The purpose in making these heavy applications is to try to determine the climatic possibilities in crop yields by removing the limitations of inadequate fertility.

Series 400 and 500 were cropped in corn and oats from 1902 to 1910, but the corresponding plots were treated the same as in the three-year rotation. Beginning with 1911, the five series have been used for a combination rotation, wheat, corn, oats, and clover being rotated for five years on four fields, while alfalfa occupies the fifth field, which is then to be brought under the four-crop system to make place for alfalfa on one of the other fields for another five-year period, and so on. (See Table 6.)

TABLE 5.—YIELDS PER ACRE, THREE-YEAR AVERAGES: URBANA FIELD
BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Serial plot No.	First rotation, 1902-1904						Second rotation, 1905 1907							Th	
	Soil treat-ment	Corn, bu.	Oats, bu.	Hay, tons	Value of 3 crops		Soil treat-ment	Corn, bu.	Oats, bu.	Clover, tons	Value of 3 crops		Soil treat ment	Corn, bu.
					Lower prices	Higher prices					Lower prices	Higher prices		
1	0........	75.4	48.8	.49	$43.48	$62.12	0......	71.5	46.6	2.07	$52.56	$75.09	0......	49.4
2	Le......	77.4	45.1	.44	42.80	61.14	Le.....	68.5	52.0	1.83	51.34	73.35	R......	51.5
3	0........	75.3	50.4	.41	43.33	61.91	M.....	80.5	54.8	2.19	58.84	84.07	M.....	69.3
4	LeL.....	78.4	47.3	.42	43.62	62.32	LeL....	72.3	58.6	1.98	55.57	79.39	RL....	58.1
5	L.......	80.8	58.2	.44	47.66	68.08	ML....	84.8	59.8	2.46	63.64	90.92	ML....	74.9
6	LeLP....	88.0	52.5	.50	49.00	70.00	LeLP..	90.4	70.7	2.69	70.26	100.38	RLP....	83.8
7	LP......	88.8	56.6	.98	53.79	76.84	MLP...	93.2	71.6	3.47	76.96	109.94	MLP...	86.6
8	LeLPK..	90.1	48.3	.64	49.53	70.77	LeLPK	93.8	71.7	3.06	74.32	106.18	RLPK	86.7
9	LPK....	90.5	54.3	1.34	56.26	80.37	MLPK	95.6	66.9	3.73	78.30	111.86	MLPK	90.9
10	LPK....	86.5	53.2	1.23	53.78	76.83	MxLPx	90.1	62.9	2.86	69.17	98.81	MxLPx	81.3

Le=legume cover crop; L=lime; P=phosphorus; K=potassium; M=manure; x=extra heavy applications of residues (corn stalks, straw of wheat and oats, and all legumes except seed).

TABLE 6.—YIELDS PER ACRE, FOUR-YEAR AVERAGES, 1911-1914: URBANA FIELD
BROWN SILT LOAM PRAIRIE; EARLY WISCONSIN GLACIATION

Serial plot No.	Soil treatment	Wheat, bu.	Corn, bu.	Oats, bu.	Soybeans-3, tons (bu.)	Clover-1, tons (bu.)	Alfalfa, tons	Value of 5 crops Lower prices	Value of 5 crops Higher prices
1	0........	18.3	50.8	39.8	1.60	1.70	1.70	$65.00	$92.87
2	R........	19.7	53.8	40.6	(20.1)	(.74)	1.27	64.72	92.47
3	M........	20.3	59.3	48.8	1.60	1.43	1.13	67.44	96.35
4	RL......	22.3	55.7	42.8	(19.0)	(1.03)	1.19	67.20	96.00
5	ML.....	24.9	58.6	51.6	1.66	1.94	1.67	76.19	108.84
6	RLP....	37.4	62.2	58.7	(21.0)	(2.48)	2.69	98.58	140.83
7	MLP....	36.6	63.8	60.9	1.88	2.90	2.63	98.36	140.51
8	RLPK...	36.1	58.9	59.1	(22.2)	(1.41)	2.58	94.61	135.16
9	MLPK..	35.3	59.6	65.1	2.09	2.72	2.66	98.15	140.22
10	MxLPx..	43.5	55.7	67.2	2.14	2.94	2.84	105.02	150.03

From 1911 to 1914 soybeans were substituted three years because of clover failure, and three-fourths of the soybeans and one-fourth of the clover are used to compute values. Alfalfa from the 1911 seeding so nearly failed that after cutting one crop in 1912, the field was plowed and reseeded. The average yield reported for alfalfa in Table 6 is one-fourth of the combined crops of 1912, 1913, and 1914.

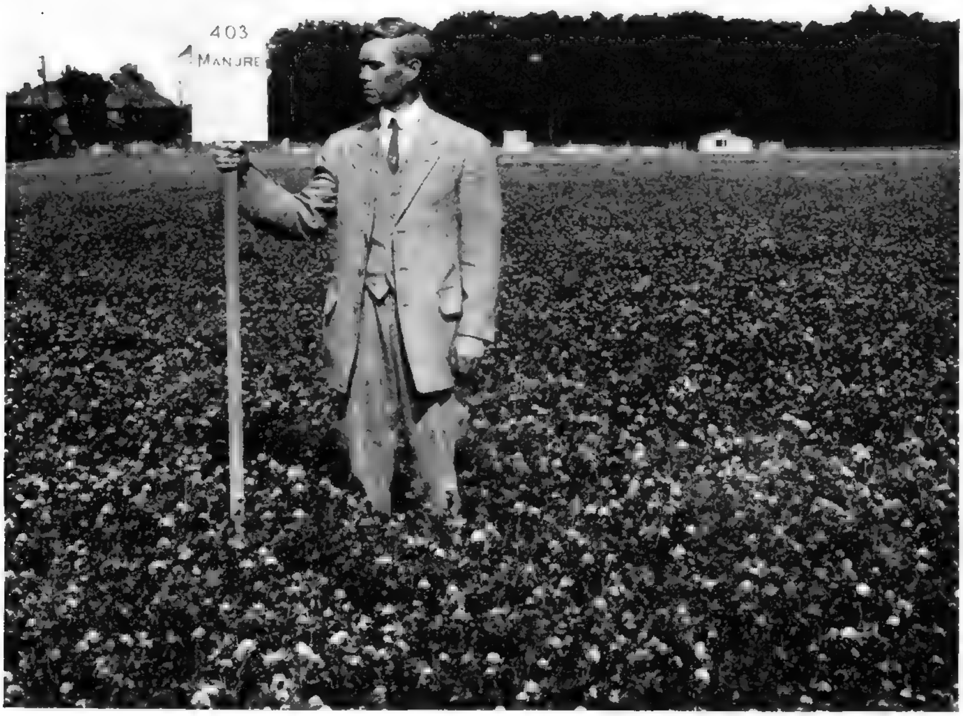


PLATE 3.—CLOVER IN 1913 ON URBANA FIELD
FARM MANURE APPLIED
YIELD, 1.43 TONS PER ACRE

The "higher prices" allowed for produce are $1 a bushel for wheat and soybeans, 50 cents for corn, 40 cents for oats, $10 for clover seed, and $10 a ton for hay; while the "lower prices" are 70 percent of these values, or 70 cents for wheat and soybeans, 35 cents for corn, 28 cents for oats, $7 for clover seed, and $7 a ton for hay. The double set of values is used to emphasize the fact that a given practice may or may not be profitable, depending upon the prices of farm produce. The lower prices are conservative, and unless otherwise stated, they are the values regularly used in the discussion of results. It should be understood that the increase produced by manures and fertilizers requires increased expense for binding twine, shocking, stacking, baling, threshing, hauling, storing, and marketing. Measured by the average Illinois prices for the past ten years, these lower values are high enough for farm crops standing in the field ready for the harvest.

The cost of limestone delivered at the farmers' railroad station in carload lots averages about $1.25 per ton. Steamed bone meal in carloads costs from $25 to $30 per ton. Fine-ground raw rock phosphate containing from 260 to 280 pounds of phosphorus, or as much as the bone meal contains, ton for ton, but in less readily available form, usually costs the farmer from $6.50 to $7.50 per ton in carloads. (Acid phosphate carrying half as much phosphorus, but in soluble form, commonly costs from $15 to $17 per ton delivered in carload lots

PLATE 4.—CLOVER IN 1913 ON URBANA FIELD
FARM MANURE, LIMESTONE, AND PHOSPHORUS APPLIED
YIELD, 2.90 TONS PER ACRE

in central Illinois.) Under normal conditions potassium costs about 6 cents a pound, or $2.50 per acre per annum for the amount applied in these experiments, the same as the cost of 200 pounds of steamed bone meal at $25 per ton.

To these cash investments must be added the expense of hauling and spreading the materials. This will vary with the distance from the farm to the railroad station, with the character of roads, and with the farm force and the immediate requirements of other lines of farm work. It is the part of wisdom to order such materials in advance to be shipped when specified, so that they may be received and applied when other farm work is not too pressing and, if possible, when the roads are likely to be in good condition.

The practice of seeding legume cover crops in the cornfield at the last cultivation where oats are to follow the next year has not been found profitable, as a rule, on good corn-belt soil; but the returning of the crop residues to the land may maintain the nitrogen and organic matter equally as well as the hauling and spreading of farm manure,—and this makes possible permanent systems of farming on grain farms as well as on live-stock farms, provided, of course, that other essentials are supplied. (Clover with oats or wheat, as a cover crop to be plowed under for corn, often gives good results.)

At the lower prices for produce, manure (6 tons per acre) was worth $1.05 a ton as an average for the first three years it was applied (1905 to 1907). The next rotation the average application of 10.21 tons per acre on Plot 3 was worth $10.09, or 99 cents a ton. The last four years, 1911 to 1914, the average amount applied (once for the rotation) on Plot 3 was 11.35 tons per acre, worth $6.42, or 57 cents a ton, as measured by its effect on the wheat, corn, oats, soybeans, and clover. Thus, as an average of the ten years' results, the farm manure applied to Plot 3 has been worth 84 cents a ton on common corn-belt prairie soil, with a good crop rotation including legumes. During the last rotation period moisture has been the limiting factor to such an extent as probably to lessen the effect of the manure.

Aside from the crop residues and manure, each addition affords a duplicate test as to its effect. Thus the effect of limestone is ascertained by comparing Plots 4 and 5, not with Plot 1, but with Plots 2 and 3; and the effect of phosphorus is ascertained by comparing Plots 6 and 7 with Plots 4 and 5, respectively.

As a general average the plots receiving limestone have produced $1.22 an acre a year more than those without limestone, and this corresponds to more than $6 a ton for all of the limestone applied; but the amounts used before 1911 were so small and the results vary so greatly with the different plots, crops, and seasons that final conclusions cannot be drawn until further data are secured, the first 2-ton applications having been completed only for 1914. However, all comparisons by rotation periods show some increase for limestone, varying from 82 cents on three acres (Plot 4) during the first rotation, to $8.75 on five acres (Plot 5) as an average of the last four years; and the need of limestone for best results and highest profits seems well established.

As an average of duplicate trials (Plots 6 and 7), phosphorus in bone meal produced increases valued at $1.92 per acre per annum for the first three years and at $4.67 for the next three; and the corresponding subsequent average increases from bone meal and raw phosphate (one-half plot of each) were $5.12 for the third rotation and $5.36 for the last four years, 1911 to 1914. The annual

expense per acre for phosphorus is $2.80 in bone meal at $28 a ton, or $2.10 for rock phosphate at $7 a ton.

Potassium, applied at an estimated cost of $2.50 an acre a year, seemed to produce slight increases, as an average, during the first and second rotations; but subsequently those increases have been slightly more than lost in reduced average yields, the net result to date being an average loss of $2.53 per acre per annum, including the cost of the potassium.

Thus phosphorus nearly paid its cost during the first rotation, and has subsequently paid its annual cost and about 100 percent net profit; while potassium, as a general average, has produced no effect, and money spent for its application has been lost. These field results are in harmony with what might well be expected on land naturally containing in the plowed soil of an acre only about 1,200 pounds of phosphorus and more than 36,000 pounds of potassium.

The total value of five average crops harvested from the untreated land during the last four years is $65. Where limestone and phosphorus have been used together with organic manures (either crop residues or farm manure), the corresponding value exceeds $98. Thus 200 acres of the properly treated land would produce as much in crops and in value as 300 acres of the untreated land.

The excessive applications on Plot 10 have usually produced rank growth of straw and stalk with the result that oats have often lodged badly and corn has frequently suffered from drouth and eared poorly. Wheat, however, has as an average yielded best on this plot. The largest yield of corn on Plot 10 was 118 bushels per acre in 1907.

RESULTS OF EXPERIMENTS OF SIBLEY FIELD

Table 7 gives the results obtained during twelve years from the Sibley soil experiment field located in Ford county on the typical brown silt loam prairie of the Illinois corn belt.

Previous to 1902 this land had been cropped with corn and oats for many years under a system of tenant farming, and the soil had become somewhat deficient in active organic matter. While phosphorus was the limiting element of plant food, the supply of nitrogen becoming available annually was but little in excess of the phosphorus, as is well shown by the corn yields for 1903, when the addition of phosphorus produced an increase of 8 bushels, nitrogen produced no increase, but nitrogen and phosphorus together increased the yield by 15 bushels.

After six years of additional cropping, however, nitrogen appeared to become the most limiting element, the increase in the corn in 1907 being 9 bushels from nitrogen and only 5 bushels from phosphorus, while both together produced an increase of 33 bushels. By comparing the corn yields for the four years 1902, 1903, 1906, and 1907, it will be seen that the untreated land apparently grew less productive, whereas, on land receiving both phosphorus and nitrogen, the yield appreciably increased, so that in 1907, when the untreated rotated land produced only 34 bushels of corn per acre, a yield of 72 bushels (more than twice as much) was produced where lime, nitrogen, and phosphorus had been applied, altho the two plots produced exactly the same yield (57.3 bushels) in 1902.

Even in the unfavorable season of 1910 the yield of the highest producing plot exceeded the yield of the same plot in 1902, while the untreated land produced less than half as much as it produced in 1902. The prolonged drouth of 1911 resulted in almost a failure of the corn crop, but nevertheless the effect of soil treatment was seen. Phosphorus appeared to be the first limiting element again in 1909, 1910, and 1911; while the lodging of oats, especially on the nitrogen plots, in the exceptionally favorable season of 1912, produced very irregular results. In 1913, wheat averaged 6.6 bushels without nitrogen or phosphorus

TABLE 7.—CROP YIELDS IN SOIL EXPERIMENTS, SIBLEY FIELD

Brown silt loam prairie; early Wisconsin glaciation		Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Corn 1906	Corn 1907	Oats 1908	Wheat 1909	Corn 1910	Corn 1911	Oats 1912	Wheat 1913
Plot	Soil treatment applied	Bushels per acre											
101	None	57.3	50.4	74.4	29.5	36.7	33.9	25.9	25.3	26.6	20.7	84.4	5.5
102	Lime	60.0	54.0	74.7	31.7	39.2	38.9	24.7	28.8	34.0	22.2	85.6	6.8
103	Lime, nitro.	60.0	54.3	77.5	32.8	41.7	48.1	36.3	19.0	29.0	22.4	25.3	18.3
104	Lime, phos.	61.3	62.3	92.5	36.3	44.8	43.5	25.6	32.2	52.0	31.6	92.3	10.7
105	Lime, potas.	56.0	49.9	74.4	30.2	37.5	34.9	22.2	23.2	34.2	21.6	83.1	7.5
106	Lime, nitro., phos.	57.3	69.1	88.4	45.2	68.5	72.3	45.6	33.3	55.6	35.3	42.2	24.7
107	Lime, nitro., potas.	53.3	51.4	75.9	37.7	39.7	51.1	42.2	25.8	46.2	20.1	55.6	19.2
108	Lime, phos., potas.	58.7	60.9	80.0	39.8	41.5	39.8	27.2	28.5	43.0	31.8	79.7	11.8
109	Lime, nitro., phos., potas.	58.7	65.9	82.5	48.0	69.5	80.1	52.8	35.0	58.0	35.7	57.2	24.5
110	Nitro., phos., potas.	60.0	60.1	85.0	48.5	63.3	72.3	44.1	30.8	64.4	31.5	54.1	18.0
	Increase: Bushels per Acre												
	For nitrogen	.0	.3	2.8	1.1	2.5	9.2	11.6	-9.8	-5.0	.2	-60.3	11.5
	For phosphorus	1.3	8.3	17.8	4.6	5.6	4.6	.9	3.4	18.0	9.4	6.7	3.9
	For potassium	-4.0	-4.1	-.3	-1.5	-1.7	-4.0	-2.5	-5.6	.2	-.6	-2.5	.7
	For nitro., phos. over phos.	-4.0	6.8	-4.1	8.9	23.7	28.8	20.0	1.1	3.6	3.7	-50.1	14.0
	For phos., nitro. over nitro	-2.7	14.8	10.9	12.4	24.8	24.2	9.3	14.3	26.6	12.9	16.9	6.4
	For potas., nitro., phos. over nitro., phos.	1.4	-3.2	-5.9	2.8	1.0	7.8	7.2	1.7	2.4	.4	15.0	-.2

Value of Crops per Acre in Twelve Years

Plot	Soil treatment applied	Total value of twelve crops: Lower prices	Total value of twelve crops: Higher prices
101	None	$172.89	$246.98
102	Lime	186.51	266.45
103	Lime, nitrogen	177.44	253.49
104	Lime, phosphorus	217.78	311.11
105	Lime, potassium	167.32	239.03
106	Lime, nitrogen, phosphorus	246.91	352.73
107	Lime, nitrogen, potassium	198.16	283.08
108	Lime, phosphorus, potassium	204.90	292.71
109	Lime, nitrogen, phosphorus, potassium	257.91	368.45
110	Nitrogen, phosphorus, potassium	242.47	346.38

Value of Increase per Acre in Twelve Years

	Lower prices	Higher prices
For nitrogen	-$ 9.07	-$12.96
For phosphorus	31.27	44.66
For *nitrogen* and phosphorus over phosphorus	29.13	41.62
For *phosphorus* and nitrogen over nitrogen	69.47	99.24
For *potassium*, nitrogen, and phosphorus over nitrogen and phosphorus	11.00	15.72

(Plots 101, 102, 105) and 22.4 bushels where both nitrogen and phosphorus were added (Plots 106, 109, 110).

In the lower part of Table 7 are shown the total values per acre of the twelve crops from each of the ten different plots, the amounts varying from $167.32 to $257.91, with corn valued at 35 cents a bushel, oats at 28 cents, and wheat at 70 cents. Phosphorus without nitrogen has produced $31.27 in addition to the increase by lime, but with nitrogen it has produced $69.47 above the crop values where only lime and nitrogen have been used. The results show that in 26 cases out of 48 the addition of potassium has decreased the crop yields. Even when applied in addition to phosphorus, and with no effort to liberate potassium from the soil by adding organic matter, potassium has produced no increase in crop values as an average of the results from Plots 108 and 109.

By comparing Plots 101 and 102, and also 109 and 110, it is seen that lime has produced an average increase of $14.53, or $1.21 an acre a year. This increase on these plots is practically the same as at Urbana, and it suggests that the time is here when limestone must be applied to some of these brown silt loam soils.

While nitrogen, on the whole, has produced an appreciable increase, especially on those plots to which phosphorus has also been added, it has cost, in commercial form, so much above the value of the increase produced that the only conclusion to be drawn, if we are to utilize this fact to advantage, is that the nitrogen must be secured from the air.

RESULTS OF EXPERIMENTS ON BLOOMINGTON FIELD

Space is taken to insert Tables 8 and 9, giving all results thus far obtained from the Bloomington soil experiment field, which is also located on the brown silt loam prairie soil of the Illinois corn belt.

The general results of the thirteen years' work on the Bloomington field tell much the same story as those from the Sibley field. The rotations have differed since 1905 by the use of clover and the discontinuing of the use of commercial nitrogen on the Bloomington field,—in consequence of which phosphorus without commercial nitrogen, on the Bloomington field, has produced an even larger increase ($99.85) than has been produced by phosphorus and nitrogen over nitrogen on the Sibley field ($69.47).

It should be stated that a draw runs near Plot 110 on the Bloomington field, that the crops on that plot are sometimes damaged by overflow or imperfect drainage, and that Plot 101, occupies the lowest ground on the opposite side of the field. In part because of these irregularities and in part because only one small application has been made, no conclusions can be drawn in regard to lime. Otherwise all results reported in Table 8 are considered reliable. They not only furnish much information in themselves, but they also offer instructive comparison with the Sibley field.

Wherever nitrogen has been provided, either by direct application or by the use of legume crops, the addition of the element phosphorus has produced very marked increases, the average yearly increase for the Bloomington field being worth $7.02 an acre. This is $4.52 above the cost of the phosphorus in 200 pounds of steamed bone meal, the form in which it is applied on the Sibley and the Bloomington fields. On the other hand, the use of phosphorus without nitrogen

TABLE 8.—CROP YIELDS IN SOIL EXPERIMENTS, BLOOMINGTON FIELD

Plot	Brown silt loam prairie; early Wisconsin glaciation Soil treatment applied	Corn 1902	Corn 1903	Oats 1904	Wheat 1905	Clover 1906	Corn 1907	Corn 1908	Oats 1909
		Bushels or tons per acre							
101	None	30.8	63.9	54.8	30.8	.39	60.8	40.3	46.4
102	Lime	37.0	60.3	60.8	28.8	.58	63.1	35.3	53.6
103	Lime, crop residues[1]	35.1	59.5	69.8	30.5	.46	64.3	36.9	49.4
104	Lime, phosphorus	41.7	73.0	72.7	39.2	1.65	82.1	47.5	63.8
105	Lime, potassium	37.7	56.4	62.5	33.2	.51	64.1	36.2	45.3
106	Lime, residues,[1] phosphorus	43.9	77.6	85.3	50.9	([3])	78.9	45.8	72.5
107	Lime, residues,[1] potassium	40.4	58.9	66.4	29.5	.81	64.3	31.0	51.1
108	Lime, phosphorus, potassium	50.1	74.8	70.3	37.8	2.36	81.4	57.2	59.5
109	Lime, residues,[1] phosphorus, potassium	52.7	80.9	90.5	51.9	([3])	88.4	58.1	64.2
110	Residues, phosphorus, potassium	52.3	73.1	71.4	51.1	([3])	78.0	51.4	55.3
	Increase: Bushels or Tons per Acre								
	For residues	–1.9	–.8	9.0	1.7	–.12	1.2	1.6	–4.2
	For phosphorus	4.7	12.7	11.9	10.4	1.07	19.0	12.2	10.2
	For potassium	.7	–3.9	1.7	4.4	–.07	1.0	.9	–8.3
	For residues, phosphorus over phosphorus	2.2	4.6	12.6	11.7	–1.65	–3.2	–1.7	8.7
	For phosphorus, residues over residues	8.8	18.1	15.5	20.4	–.46	14.6	8.9	23.1
	For potassium, residues, phosphorus, over res., phos.	8.8	3.3	5.2	1.0	.00	9.5	12.3	–8.3

[1]Commercial nitrogen was used 1902-1905.
[2]The figures in parenthses mean bushels of seed; the others, tons of hay.
[3]Clover smothered by previous wheat crop.

TABLE 9.—VALUE OF CROPS PER ACRE IN THIRTEEN YEARS, BLOOMINGTON FIELD

Plot	Soil treatment applied	Total value of thirteen crops	
		Lower prices	Higher prices
101	None	$186.83	$266.90
102	Lime	186.76	266.80
103	Lime, residues	193.83	276.90
104	Lime, phosphorus	286.61	409.45
105	Lime, potassium	190.53	272.19
106	Lime, residues, phosphorus	285.03	407.19
107	Lime, residues, potassium	191.10	273.00
108	Lime, phosphorus, potassium	294.91	421.31
109	Lime, residues, phosphorus, potassium	284.47	406.39
110	Residues, phosphorus, potassium	259.10	370.15

Value of Increase per Acre in Thirteen Years

For residues	$ 7.07	$ 10.10
For phosphorus	99.85	142.65
For *residues* and phosphorus over phosphorus	-1.58	-2.26
For *phosphorus* and residues over residues	91.20	130.29
For *potassium,* residues, and phosphorus over residues and phosphorus	-.56	-.80

will not maintain the fertility of the soil (see Plots 104 and 106, Sibley field). As the only practical and profitable method of supplying nitrogen, a liberal use of clover or other legumes is suggested, the legume to be plowed under either directly or as manure, preferably in connection with the phosphorus applied, especially if raw rock phosphate is used.

From the soil of the best treated plots on the Bloomington field, 180 pounds per acre of phosphorus, as an average, has been removed in the thirteen crops. This is equal to 15 percent of the total phosphorus contained in the surface soil of an acre of the untreated land. In other words, if such crops could be grown

PLATE 5.—CORN IN 1912 ON BLOOMINGTON FIELD
ON LEFT, RESIDUES, LIME, AND POTASSIUM: YIELD, 58.9 BUSHELS
ON RIGHT, RESIDUES, LIME, AND PHOSPHORUS: YIELD, 86.1 BUSHELS

for eighty years, they would require as much phosphorus as the total supply in the ordinary plowed soil. The results plainly show, however, that without the addition of phosphorus such crops cannot be grown year after year. Where no phosphorus has been applied, the crops have removed only 120 pounds of phosphorus in the thirteen years, which is equivalent to only 10 percent of the total amount (1,200 pounds) present in the surface soil at the beginning of the experiment in 1902. The total phosphorus applied from 1902 to 1914, as an average of all plots where it has been used, has amounted to 325 pounds per acre and has cost $32.50. This has paid back $97.20, or 300 percent on the investment; whereas potassium, used in the same number of tests and at the same cost, has paid back only $2.20 per acre in the thirteen years, or less than 7 percent of its cost. Are not these results to be expected from the composition of such soil and the requirements of crops? (See Table 2, page 5, and also Table A in the Appendix.)

Nitrogen was applied to this field, in commercial form only, from 1902 to 1905; but clover was grown in 1906 and 1910, and a cover crop of cowpeas after the clover in 1906. The cowpeas were plowed under on all plots, and the 1910

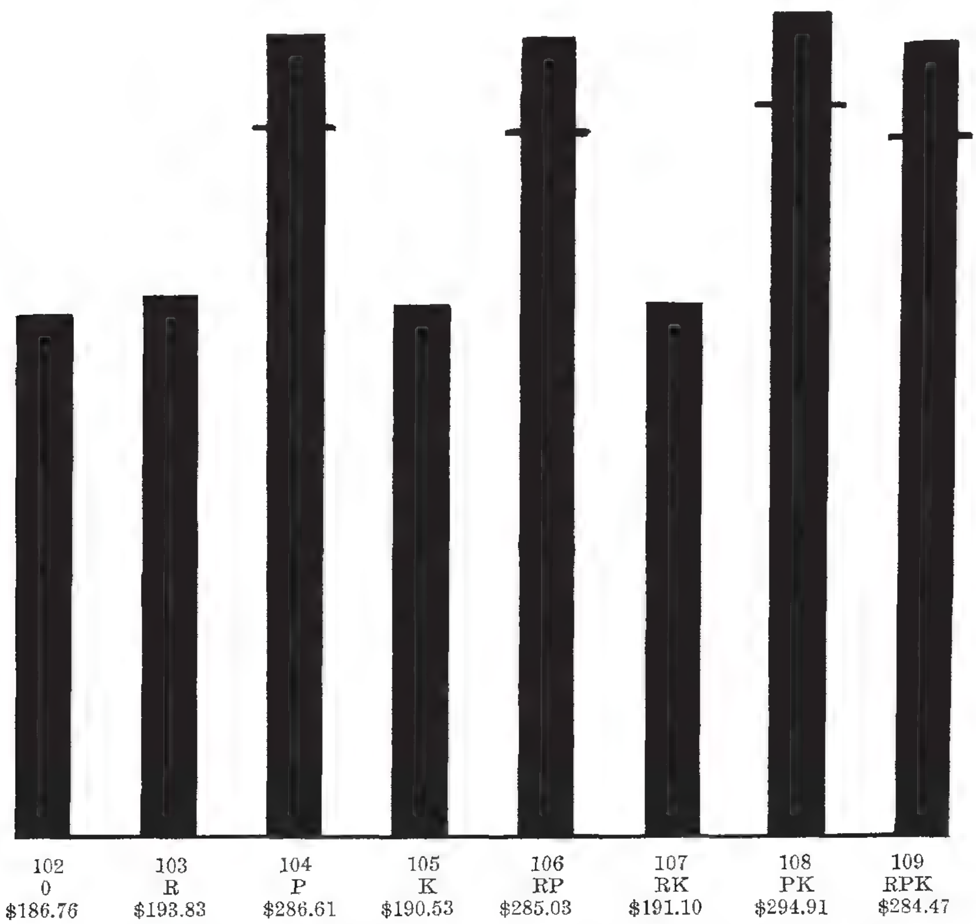


PLATE 6. CROP VALUES FOR THIRTEEN YEARS, BLOOMINGTON EXPERIMENT FIELD
(R=residues; P=phosphorus; K=potassium, or kalium)

clover (except the seed) was plowed under on five plots (103, 106, 107, 109, and 110). Straw and corn stalks have also been returned to these plots in recent years. The effect of returning these residues to the soil has been appreciable since 1910 (an average increase on Plots 106 and 109 of 4.5 bushels of wheat, 5.4 bushels of corn, and 4.3 bushels of oats) and probably will be more marked on subsequent crops. Indeed, the large crops of corn, oats, and wheat grown on Plots 104 and 108 during the thirteen years have drawn their nitrogen very largely from the natural supply in the organic matter of the soil. The roots and stubble of clover contain no more nitrogen than the entire plant takes from the soil alone, but they decay rapidly in contact with the soil and probably hasten the decomposition of the soil humus and the consequent liberation of the soil nitrogen. But of course there is a limit to the reserve stock of humus and nitrogen remaining in the soil, and the future years will undoubtedly witness a gradually increasing difference between Plots 104 and 106, and between Plots 108 and 109, in the yields of grain crops.

Plate 6 shows graphically the relative values of the thirteen crops for the eight comparable plots, Nos. 102 to 109. The cost of the phosphorus is indicated

TABLE 10.—FERTILITY IN THE SOILS OF LAKE COUNTY, ILLINOIS

Average pounds per acre in 4 million pounds of subsurface (about $6\frac{2}{3}$ to 20 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity
	Upland Prairie Soils								
1226	Brown silt loam	91 050	7 940	1 960	101 020	29 810	19 310		110
1060	Brown sandy loam	4 280	440	1 000	53 720	7 200	12 080		40
	Upland Timber Soils								
1234	Yellow-gray silt loam	26 090	2 630	1 300	106 140	31 660	14 190		310
1035	Yellow silt loam	23 980	2 720	1 620	136 020	40 600	13 460		60
1064	Yellow-gray sandy loam	18 960	2 040	1 840	71 040	19 920	17 560		160
1064.4	Yellow-gray sandy loam on gravel	10 000	680	1 000	69 640	13 920	20 520		40
1281	Dune sand	18 520	720	1 160	53 840	14 280	18 040		80
1090	Gravelly loam	16 200	1 760	1 600	66 560	52 600	75 920	255 400	
	Terrace Soils								
1527	Brown silt loam over gravel	55 560	4 760	1 680	78 440	16 920	14 880		200
1564.4	Yellow-gray sandy loam on gravel	30 320	2 400	2 080	86 880	24 880	15 160		160
1560.4	Brown sandy loam on gravel	21 080	2 200	1 200	82 440	28 160	36 240	72 520	
1590.4	Gravelly loam on gravel	32 240	2 840	2 360	77 880	21 280	19 200	2 720	
	Swamp and Bottom-Land Soils								
1401	Deep peat (slightly decomposed moss)	988 560	32 700	1 000	3 820	7 640	18 080		1 940
1401	Deep peat	535 240	66 050	2 410	8 180	11 880	53 010		460
1402	Medium peat on clay	295 140	24 820	2 140	33 480	18 500	38 660	3 860	
1402.2	Medium peat on sand	388 940	25 020	1 340	15 200	15 400	35 760	8 540	
1403	Shallow peat on clay	181 560	14 680	2 160	86 360	80 880	151 040	440 800	
1410	Peaty loam	40 620	3 760	1 300	52 460	47 720	79 200	264 300	
1450	Black mixed loam	115 760	9 840	2 600	78 400	24 920	33 560	4 400	
1454	Mixed loam (bottom land)	117 340	10 140	3 320	72 840	94 240	191 800	Often	
1482	Beach sand	6 080	240	600	32 280	23 080	36 400	25 760	

by that part of the diagram above the short crossbars. It should be kept in mind that no value is assigned to clover plowed under except as it reappears in the increase of subsequent crops. Plots 106 and 109 are heavily handicapped because of the clover failure on those plots in 1906 and the poor yield of clover seed in 1910, whereas Plots 104 and 108 produced a fair crop in 1906 and a very large crop in 1910. Plot 106, which receives the most practical treatment for permanent agriculture (RLP), has produced a total value in thirteen years only $1.58 below that from Plot 104 (LP). (See also table on last page of cover.)

THE SUBSURFACE AND SUBSOIL

In Tables 10 and 11 are recorded the amounts of plant food in the subsurface and the subsoil strata of the Lake county soils, but it should be remembered that these supplies are of little value unless the top soil is kept rich. Probably the most important information contained in these tables is that the subsoils are usually rich in limestone. This fact probably accounts for the moderate success with alfalfa on some Lake county farms, even where limestone has not been applied. If alfalfa is given a good start with manure or by a favorable season, until the roots reach the limestone subsoil, subsequent addition of limestone to the plowed soil may not be of much importance.

TABLE 11.—FERTILITY IN THE SOILS OF LAKE COUNTY, ILLINOIS

Average pounds per acre in 6 million pounds of subsoil (about 20 to 40 inches)

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total potassium	Total magnesium	Total calcium	Limestone present	Soil acidity
	Upland Prairie Soils								
1226	Brown silt loam.....	33 940	3 350	2 480	158 810	167 400	257 290	998 570	
1060	Brown sandy loam...	6 420	660	1 500	80 580	10 860	18 120		60
	Upland Timber Soils								
1234	Yellow-gray silt loam	27 080	2 970	2 470	157 500	165 470	261 330	1 066 470	
1035	Yellow silt loam.....	22 380	14 700	2 460	178 710	198 000	263 940	1 179 780	
1064.4	Yellow gray sandy loam on gravel....	23 100	1 680	2 340	119 880	45 060	36 000		60
1281	Dune sand	27 780	1 080	1 740	80 760	21 420	27 060		120
1090	Gravelly loam	24 300	2 640	2 400	99 840	78 900	113 880	383 100	
	Terrace Soils								
1527	Brown silt loam over gravel	29 040	2 760	2 220	124 440	42 180	34 500	32 220	
1560.4	Brown sandy loam on gravel	12 960	1 380	2 520	108 360	176 880	278 340	1 232 460	
	Swamp and Bottom-Land Soils								
1401	Deep peat (slightly decomposed moss) ..	1 443 030	48 870	1 170	6 060	9 900	30 600		2 310
1401	Deep peat	1 269 080	99 070	3 620	12 270	17 820	79 520		690
1402	Medium peat on clay.	99 180	6 840	2 760	165 780	200 640	323 040	1 258 860	
1402.2	Medium peat on sand	55 980	3 000	1 860	34 860	91 620	153 840	478 020	
1403	Shallow peat on clay.	58 560	3 360	2 280	127 260	209 400	589 860	1 980 120	
1410	Peaty loam	19 410	1 260	1 350	85 050	111 030	183 510	744 390	
1450	Black mixed loam....	43 620	3 420	1 980	122 880	57 060	74 760	183 840	
1454	Mixed loam (bottom land).............	72 480	5 730	4 380	112 470	140 400	349 710	Often	
1482	Beach sand	9 120	360	900	48 420	34 620	54 600	28 640	

INDIVIDUAL SOIL TYPES

(a) Upland Prairie Soils

The upland prairie soils of Lake county cover 140.38 square miles, or 29.08 percent of the entire area of the county. They are usually quite dark in color, owing to their large organic-matter content. They occupy the less rolling and comparatively level land.

Brown Silt Loam (1026 *and* 1226)

Brown silt loam is a very important and somewhat extensive type in this county, covering an area of 137.50 square miles, or 28.48 percent of the entire area of the county. It occupies much of the less rolling land, a considerable proportion of which needs artificial drainage. The presence of kettle-holes in some places makes complete drainage rather difficult; and small ponds are frequently found. Many local areas of yellow-gray silt loam, sandy loam, and peat, too small to show on the map, are also interspersed.

The surface soil, 0 to 6⅔ inches, is a brown silt loam, varying from a yellowish brown on the more rolling areas to a dark brown or black on the more nearly level and poorly drained tracts. In physical composition it varies to some extent, but normally contains from 50 to 70 percent of the different grades of silt. The clay content, as well as the organic-matter content, increases as the type approaches the black mixed loam (1450) of the swampy areas. On account of the complex character of the type, the amount of organic matter also is quite variable, ranging from 5.5 to 9.9 percent, but it averages about 7.6 percent, or 76 tons per acre. Where this type passes into the yellow-gray silt loam, the content of organic matter becomes much lower and the type much more variable. The slightly higher points, perhaps not more than a fraction of an acre in extent, may be decidedly gray or yellow, while the lower adjoining parts may be quite dark, thus giving an extremely variable phase of brown silt loam impossible to indicate on the soil map.

The subsurface is represented by a stratum varying from 6 to 15 inches in thickness. This variation is due to changing topography and the effect of erosion, the stratum becoming thinner on the more rolling areas. Less organic matter has accumulated on the more rolling areas than on the more nearly level tracts, and to a less depth. In physical composition the subsurface varies the same as the surface soil, but it normally contains a slightly larger amount of clay and a smaller amount of organic matter. The organic matter varies from 2.7 to 4.2 percent, with an average of 3.8 percent, or 38 tons per acre, or half as much as is in the surface soil. In color the subsurface varies from a dark brown or almost black to a light yellowish brown; it becomes lighter with depth, passing into the subsoil at from 12 to 22 inches.

The natural subsoil begins 12 to 22 inches beneath the surface and extends to an indefinite depth but is sampled to 40 inches. It varies from a yellow to a drabbish yellow clayey material sometimes composed of boulder clay, or drift. In some of the flat areas where material has washed in from the higher surrounding parts, the subsoil to a depth of 40 inches does not reach the boulder

clay. In many cases the stratum of gravel at 16 to 20 inches interferes with the collecting of samples.

Where properly drained, brown silt loam requires only the addition of phosphorus, limestone, and organic manures for the improvement and permanent maintenance of its productive power. As an average, phosphorus is present in the plowed soil of an acre to the extent of 1,400 pounds, compared with about 7,500 pounds of nitrogen and 47,000 pounds of potassium, altho the lighter phase, as where the type is much worn, contains as low as 1,200 pounds of phosphorus and 5,000 of nitrogen. No long-continued field experiments have been conducted by the University on this type of soil in the late Wisconsin glaciation, but the results already reported from the fields at Urbana, Sibley, and Bloomington (pages 9, 15, and 17), considered together with the composition of the soil, leave no doubt as to the wisdom of adding phosphorus to this soil and of the foolishness of spending money for potassium.

This type contains no limestone to a depth of 20 to 30 inches, and liberal use of this material should prove beneficial for clover and alfalfa, even tho the lower subsoil usually contains abundance of limestone. Farm manures, crop residues, or legume crops plowed under are needed, not only to provide nitrogen, but also to give activity to the soil for the liberation of plant food and to maintain good tilth, or good physical condition.

Brown Sandy Loam (1060 *and* 1260)

Brown sandy loam occupies only a small area in the county, amounting to 2.88 square miles, 1,844 acres, or .6 percent of the entire area.

The surface soil, 0 to 6⅔ inches, consists of a brown sandy loam varying from a light or yellowish brown to a dark brown or even black color. The areas in the western part of the country are of the lighter colored phase, while those in the eastern part, particularly north of Waukegan, partake somewhat of the nature of peaty loam and vary toward that type.

The subsurface, 6⅔ to 18 or 20 inches, consists of a brown sandy loam varying with the surface. In the western areas it is quite light in color, varying to yellow. In the eastern part of the county, it is somewhat dark, and with depth becomes somewhat gray or drab, indicating poorer drainage in many cases.

The subsoil is quite variable, in some places passing into a yellowish sand, in others into a gravelly till, while in others it becomes a drab or bluish-colored sand. This last is in the poorly drained areas.

This type of soil requires for its improvement large use of organic matter. Being loose and better aerated than the brown silt loam, it suffers greater loss of that constituent, hence greater difficulty is found in maintaining it. Crop residues, legume crops, and manure must constitute the chief materials by which the organic-matter content is maintained. In phosphorus content, this type is the poorest in the county, and it is also very deficient in limestone. While the potassium content is large (25,000 pounds per acre of plowed soil), it is in part locked up in sand grains; hence, if satisfactory yields of legumes are not secured where the soil is well drained and treated with limestone and phosphorus, the addition of kainit or potassium chlorid may well be tried.

(b) UPLAND TIMBER SOILS

The upland forest soils are deficient in organic matter owing to the fact that the vegetable material from trees accumulates upon the surface and is either burned or suffers almost complete decay. Grasses which furnish large quantities of humus-forming roots do not grow to any large extent in forests. At the same time, the organic matter that had accumulated before timber began growing on these soils is being removed thru various decomposition processes, with the result that the content has become too low for best growth.

Yellow-Gray Silt Loam (1034 *and* 1234)

Yellow-gray silt loam is the most important and extensive soil type in Lake county. It is very irregularly distributed, but occupies mostly the rolling morainal areas. This type covers 196.01 square miles, 125,447 acres, or 40.59 percent of the county. It varies greatly in topography—from the characteristic billowy, or knob-and-basin, features of the moraines to the almost level morainal and intermorainal tracts.

The surface soil, 0 to 6⅔ inches, is a gray or yellowish gray silt loam, incoherent and mealy, but not granular. The physical composition varies a great deal because of the removal by erosion in some places of the thin covering of loess, thus exposing the variable drift. Many local areas of sandy or gravelly loam are found in this type, but they are too small to be shown on the map. Likewise many small areas of dark soil such as the brown silt loam or black mixed loam are found in the slight depressions; these are also too small to be shown. The amount of organic matter contained in the surface soil of this type varies from 1.8 to 3.6 percent, with an average of 2.7, or 27 tons per acre. This wide variation is due to the relation of the type to other types, the content of organic matter increasing where it grades into brown silt loam (1026 or 1226) and decreasing where it passes into yellow silt loam (1035 or 1235). In some places erosion has reduced the content of organic matter much below the normal, so that many small areas are yellow in color.

The subsurface stratum varies from 3 to 10 inches in thickness, being thinner on the more rolling areas. In color it is gray, grayish yellow, or yellow, somewhat pulverulent, but becoming more coherent and plastic with depth. On some of the areas a stratum of gravel an inch or two in thickness is encountered at a depth of 10 to 24 inches. This is formed by the washing out of the fine material from the surface drift, as may be seen on the surface of exposed drift at the present time. It has subsequently been covered with a thin deposit of loess. The amount of organic matter is very low, amounting to only 1.1 percent, or 22 tons per acre, for a stratum 13⅓ inches in thickness.

The subsoil is a yellow to a grayish yellow boulder clay. The deeper subsoil contains large amounts of limestone and shows brisk effervescence with hydrochloric acid.

In the management of this yellow-gray silt loam, one of the most essential points is the maintenance or increase of the organic matter. This is much more necessary with this type than with the brown silt loam, because this soil is naturally much more deficient in that constituent. The organic matter supplies nitrogen, liberates mineral plant food, prevents running together, and on some of the

more rolling areas, prevents washing as well as gives better tilth to the soil under all conditions.

Another essential is the application of ground limestone, so that clover, alfalfa, and other legumes may be grown more successfully. In many cases where limestone is present in the subsoil, the legume crops will grow very well, but frequently their growth may be profitably increased by the application of 2 to 5 tons per acre of limestone. Potassium is exceedingly abundant in this type of soil, while phosphorus is markedly deficient, as is readily seen from the tabular statements, which are well supported by the results already secured from the soil experiment field conducted for many years by the University of Illinois with the helpful cooperation of Mr. D. M. White, on his farm near Antioch in Lake county. (See Tables 3 and 4, pages 7 and 8.)

Yellow Silt Loam (1035 *and* 1235)

Yellow silt loam is found chiefly in the west quarter of the county where the highest part of the Valparaiso moraine occurs. The type here is not due primarily to erosion, as in most parts of the state, but to the irregularities produced in the piling up of the morainic material. Basin-like kettle-holes are found varying from 25 feet or less to 75 and possibly 100 feet in depth. Rounded knobs are also quite characteristic of this moraine. The area of this type amounts to 38.5 square miles, 24,639 acres, or 8 percent of the county.

The surface soil, 0 to 6⅔ inches, is a yellow or yellowish gray silt loam, usually containing some sand and gravel. This stratum is usually formed from drift material, the loess, if there ever was any, having been removed by erosion. Owing to its derivation, the stratum varies a great deal in physical composition. The organic-matter content averages about 1.8 percent.

The subsurface is composed of yellow drift material, as is also the subsoil.

One of the best ways to manage this type is to keep it in permanent pasture. As a rule, it cannot be satisfactorily cropped in ordinary rotations, altho it may be used very successfully for long rotations with much pasture or meadow.

Where this soil has been long cultivated and thus exposed to surface washing, it is particularly deficient in nitrogen; indeed, on such lands the low supply of nitrogen is the factor that first limits the growth of grain crops. This fact is very strikingly illustrated by the results from two pot-culture experiments reported in Tables 12 and 13, and illustrated in Plates 7 and 8.

In one experiment, a large quantity of the typical worn hill soil was collected from two different places.[1] Each lot of soil was thoroly mixed and put in ten four-gallon jars. Ground limestone was added to all the jars except the first and last in each set, those two being retained as control or check pots. The elements nitrogen, phosphorus, and potassium were added singly and in combination, as shown in Table 12.

As an average, the nitrogen applied produced a yield about eight times as large as that secured without the addition of nitrogen. While some variations in yield are to be expected, because of differences in the individuality of seed or other uncontrolled causes, yet there is no doubting the plain lesson taught by these actual trials with growing plants.

[1] Soil for wheat pots from loess-covered unglaciated area, and that for oat pots from upper Illinois glaciation.

The question arises next, Where is the farmer to secure this much-needed nitrogen? To purchase it in commercial fertilizers would cost too much; indeed, under average conditions the cost of the nitrogen in such fertilizers is greater than the value of the increase in crop yields.

But there is no need whatever to purchase nitrogen, for the air contains an inexhaustible supply of it, which, under suitable conditions, the farmer can draw upon, not only without cost, but with profit in the getting. Clover, alfalfa, cowpeas, and soybeans are not only worth raising for their own sake, but they have the power to secure nitrogen from the atmosphere if the soil contains the essential minerals and the proper nitrogen-fixing bacteria.

In order to secure further information along this line, another experiment with pot cultures was conducted for several years with the same type of worn hill soil as that used in the former experiment. The results are reported in Table 13.

To three pots (Nos. 3, 6, and 9) nitrogen was applied in commercial form, at an expense amounting to more than the total value of the crops produced. In three other pots (Nos. 2, 11, and 12) a crop of cowpeas was grown during the late summer and fall and turned under before the wheat or oats were planted.

PLATE 7.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND
(See Table 12)

TABLE 12.—CROP YIELDS IN POT CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND
(Grams per pot)

Pot No.	Soil treatment applied	Wheat	Oats
1	None	3	5
2	Limestone	4	4
3	Limestone, nitrogen	26	45
4	Limestone, phosphorus	3	6
5	Limestone, potassium	3	5
6	Limestone, nitrogen, phosphorus	34	38
7	Limestone, nitrogen, potassium	33	46
8	Limestone, phosphorus, potassium	2	5
9	Limestone, nitrogen, phosphorus, potassium	34	38
10	None	3	5
Average yield with nitrogen		32	42
Average yield without nitrogen		3	5
Average gain for nitrogen		29	37

Pots 1 and 8 served for important comparisons. After the second cover crop of cowpeas had been turned under, the yield from Pot 2 exceeded that from Pot 3; and in the subsequent years the legume green manures produced, as an average, rather better results than the commercial nitrogen. This experiment confirms that reported in Table 12, in showing the very great need of nitrogen for the improvement of this type of soil, and it also shows that nitrogen need not be purchased but that it can be obtained from the air by growing legume crops and plowing them under as green manure. Of course the soil can be very markedly improved by feeding the legume crops to live stock and returning the resulting farm manure to the land, if legumes are grown frequently enough and if the farm manure produced is sufficiently abundant and is saved and applied with care.

As a rule, it is not advisable to try to enrich this type of soil in phosphorus, for with the erosion that is sure to occur to some extent the phosphorus supply will be renewed from the subsoil.

One of the most profitable crops to grow on this land is alfalfa. To get alfalfa well started may require the use of limestone, thoro inoculation with nitrogen-fixing bacteria, and a moderate application of farm manure. If manure is not available, it is well to apply about 500 pounds per acre of acid phosphate or steamed bone meal, mix it with the soil, by disking if possible, and then plow it under. The limestone (if needed) should be applied after plowing and should be mixed with the surface soil in the preparation of the seed bed. The special

PLATE 8.—WHEAT IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND (See Table 13)

TABLE 13.—CROP YIELDS IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND AND NITROGEN FIXING GREEN MANURE CROPS

(Grams per pot)

Pot No.	Soil treatment	1903 Wheat	1904 Wheat	1905 Wheat	1906 Wheat	1907 Oats
1	None	5	4	4	4	6
2	Limestone, legume	10	17	26	19	37
11	Limestone, legume, phosphorus	14	19	20	18	27
12	Limestone, legume, phosphorus, potassium	16	20	21	19	30
3	Limestone, nitrogen	17	14	15	9	28
6	Limestone, nitrogen, phosphorus	26	20	18	18	30
9	Limestone, nitrogen, phosphorus, potassium	31	34	21	20	26
8	Limestone, phosphorus, potassium	3	3	5	3	7

purpose of this treatment is to give the alfalfa a quick start in order that it may grow rapidly and thus protect the soil from washing.

Yellow-Gray Sandy Loam (1064)

Yellow-gray sandy loam occupies only small areas in Lake county, amounting to 488 acres. It is practically all found in the western part in the most broken of the morainal ridges.

The surface soil, 0 to 6⅔ inches, is a yellow or grayish yellow sandy loam, frequently containing from 15 to 25 percent of gravel. In some small areas this gravel may be absent; its presence is due to the fact that the soil is made of a sandy till. The organic-matter content is 1.8 percent, or about 18 tons per acre.

The subsurface stratum, from 3 to 8 inches in thickness, differs from the surface in being of a lighter color, owing to the smaller amount of organic matter present, about .3 percent. At a depth of about 12 to 16 inches on much of this type, a stratum of gravelly material exists thru which it is practically impossible to bore with an auger.

The subsoil varies from a somewhat gravelly till to almost pure sand.

For the improvement of this type, the addition of organic matter and nitrogen is very essential, and limestone should be applied liberally for the best results with legumes. The porous subsoil affords such a deep feeding range for plant roots that the addition of phosphorus is not likely to be necessary or profitable.

Yellow-Gray Sandy Loam on Gravel (1064.4)

Yellow-gray sandy loam on gravel occurs only in the northwestern part of the county, and there in limited areas. The type differs but little from yellow-gray sandy loam except that it contains much more gravel in the subsoil and for that reason is less desirable. It occupies 1.48 square miles, or .3 percent of the entire area of the county. The stratum of gravel varies a great deal, both as to depth and physical composition. In depth it varies from 12 to 30 inches; in composition it is sandy, or a sand in some places, and in others a mixture of sand, gravel, and small stones not over two inches in diameter.

The management of this type should be the same as for the yellow-gray sandy loam. Alfalfa does fairly well on this type, and sweet clover would do equally well.

Dune Sand (1081 *and* 1281)

Dune sand is found in the vicinity of Fox Lake, and also along the old lake shore north of Waukegan. It covers 1.47 square miles. Its presence is due to the action of wind, and possibly the waves, in piling the sand up from the lake shore. The surface soil contains about 2.25 percent of organic matter, while the subsurface has about .8 percent.

In the management of this type, limestone should be applied and legume crops should be prominent in the rotation unless large amounts of organic matter can be added in some other form. The only other addition suggested is potassium, but this should not be applied on a large scale unless found profitable by careful trial on small areas.

For results from field experiments on sand soil, see pages 246 to 249 of Bulletin 123 of this station.[1] In the experiments there described (conducted in Tazewell county), the average value of the increase per acre per annum was $12.12 from nitrogen, $2.96 from potassium (costing $2.50), and 4 cents from phosphorus, the order of crops being corn, corn, oats, wheat, corn, corn. The nitrogen applied cost $15 in commercial form, but of course by growing legume crops, which are worth raising for their own sake, that element may be secured from the air without cost.

Gravelly Loam (1090 *and* 1290)

Gravelly loam occurs principally in the morainal regions of the northwest part of the Lake county, altho some small areas are found in other parts. The total area aggregates 611 acres, or .2 percent of the area of the county.

The surface soil is composed of a large amount of gravel, in many cases amounting to 60 or 70 percent. Occasionally small stones an inch or two in diameter are found mixed with the gravel. The organic-matter content amounts to approximately 3 percent, or 30 tons per acre. The subsurface soil contains about one-fourth as much as the surface.

This type is of very little agricultural significance. The treatment recommended is the same as that for yellow-gray sandy loam (1064). It may well be left in permanent pasture.

(c) TERRACE SOILS

Terrace soils occur along streams and were formed at a time when the streams were much larger than at present and carried large amounts of coarse material, such as sand and gravel. This overloading of the streams caused deposition along their courses which resulted in the formation of terraces, bench lands, or second bottom lands. Fine material, later deposited over this sand and gravel, forms the present soil.

Brown Silt Loam over Gravel (1527)

Brown silt loam over gravel is found along the Des Plaines river near the southern part of the county where the stream formed its widest terrace. The deposit of gravel here is not very deep, but it furnishes a very effective means for the natural drainage of these areas. This type occupies 1.85 square miles.

The surface soil, 0 to 6⅔ inches, is a brown silt loam, with some sand, but rarely containing enough to make it a sandy loam. The average amount of organic matter present is 5.4 percent, or 54 tons per acre.

The subsurface soil consists of a brown silt loam, becoming yellow at about 16 inches and passing into the subsoil at a depth of 18 inches. The subsurface stratum contains about 2.5 percent of organic matter.

The subsoil varies a great deal, in some cases containing a considerable amount of sand and fine gravel. It is generally a yellow clayey silt, pervious, and well drained. The depth to the gravel varies from 38 to 48 inches. It consists of a mixture of medium and fine gravel with some coarse sand.

This type requires practically the same management as the brown silt loam,

[1]Bulletin 123 may be had from the Experiment Station upon request.

altho in some cases there may be more need of organic matter than in some phases of the brown silt loam. Alfalfa should do well on this type.

Yellow-Gray Sandy Loam on Gravel (1564.4)

Yellow-gray sandy loam on gravel occurs only along the Des Plaines river and is limited largely to the east side of this stream. The total area is 2.25 square miles.

The surface soil, 0 to 6⅔ inches, varies in color from a yellow to a gray, and in texture from a loam to a sand. These variations are so limited in area and so badly mixed that it is impossible to represent them on the map. In some places there are slight ridges that indicate low dunes; these give rise to a very sandy phase.

The subsurface stratum is as variable as the surface. In small areas the subsurface is a sandy clay or sandy clay loam, while in others it is a yellow sand. The organic-matter content of the subsurface is higher in the more silty or clayey parts, but in the more sandy phase it contains almost no organic matter.

The subsoil varies in different parts of the Des Plaines valley. In the northern part it is decidedly gravelly, while in the southern, sand prevails. The depth to the sand or gravelly stratum varies from over 30 inches in many places to less than 15 inches in others.

In the southern half of the county this type is not under cultivation, but is almost entirely covered with a young growth of forest trees. Where it is under cultivation, the treatment should be about the same as for the yellow-gray silt loam, except as regards phosphorus. With the porous character of the soil and subsoil, and the extensive feeding range thus afforded plants, the supply of phosphorus naturally contained in this soil should be adequate for large crops.

Brown Sandy Loam on Gravel (1560.4)

Brown sandy loam on gravel is found principally along the Des Plaines river and is similar to yellow-gray sandy loam on gravel except that the forests that have recently grown up here have not reduced the organic-matter content to such a low amount. Part of the type in the southern part of the county has never been covered with forest. In topography the type shows a slight ridging, due to the action of wind in forming sand dunes or of the water in forming bars. The total area is 2.4 square miles, or .5 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, varies in color from a light to a dark brown, almost black, and in texture from a loam to a sandy loam.

The subsurface soil is a light brown loam to sandy loam, having a thickness of 5 to 12 inches with an average of 9 to 10 inches. It passes into the gravelly, sandy subsoil, which is made up of medium and fine gravel, mixed with more or less coarse sand. The depth of the gravel from the surface varies from 14 to 30 inches and even more in small local areas. The bed of gravel itself is probably not over 20 feet in depth in any place, and toward the southern part of the county it is much less than that. In many places it is being taken out for use on roads. The presence of gravel in the subsoil gives excellent drainage to this type, and in seasons of drouth, the crops may suffer because of lack of moisture.

Only the ordinary crops, as a rule, are grown on this type, but it is fairly

well adapted to the growth of alfalfa and deep-rooting crops. Manure, crop residues, or legume crops should be turned under in order to maintain the organic matter and nitrogen, but the addition of phosphorus is not likely to be profitable.

Gravelly Loam on Gravel (1590.4)

Gravelly loam on gravel covers one area of 179 acres in Section 22, Town 46 North, Range 11 East.

The surface soil, 0 to 6⅔ inches, consists of a brown, gravelly loam, the gravel present amounting to 60 to 75 percent. The content of organic matter is about 3 percent. The subsurface stratum contains even a larger amount of gravel than the surface, with a proportionately smaller amount of organic matter. A sample could not be obtained to a depth of more than 20 inches. The subsoil consists of various grades of gravel mixed with a few small stones.

This is a very poor type of soil, owing to the fact that it does not have much power for retaining moisture in times of drouth, and the plant food leaches out readily. The liberal use of legume crops and organic manures is advised.

(d) SWAMP AND BOTTOM-LAND SOILS

Deep Peat (1401)

Deep peat is found in nearly all parts of Lake county, occurring on the old beach of Lake Michigan, in the bottom lands of the streams, in the depressions of the moraines, and around the margins of many of the lakes. The total area is 38.1 square miles, 24,382 acres, or 7.89 percent of the area of the county. The deep peat is formed by the growth of both grasses and mosses. In one area in Section 35, Town 46 North, Range 10 East, the peat was found to be forming entirely by the accumulation of the sphagnum moss, independent of the growth of grasses; in other areas, both grasses and mosses contribute to the deposit.

The surface soil, 0 to 6⅔ inches, is a black or brown peat, more or less decomposed. The drained areas have undergone greater decomposition because of better aeration, while the moss-covered or grass-covered peat of the undrained areas has changed but little. The content of organic matter varies from 61 to 77 percent, with an average of 70.5 percent.

The subsurface soil, 6⅔ to 20 inches, consists of black or brown peat that usually shows the texture of the material from which it was produced.

The subsoil, from 20 to 40 inches, is usually a brown peat, altho in some small areas sand or silty material may form the subsoil below 30 inches. This latter phase is almost invariably drab in color, due to deoxidation by organic acids.

Because of lack of drainage, this type of soil in Lake county has not been largely cultivated, except in the small areas. It does, however, supply a large amount of hay that is used to a considerable extent for packing ice in the large ice houses on the shores of the lakes. As a rule, it is not desirable to attempt to drain this type by means of tiles unless they can be laid deep enough to place them in the clayey or silty subsoil. Tiles laid in peat soon get out of line.

As shown in Table 2, deep peat contains in one million pounds of surface soil about 32,000 pounds of nitrogen, 1,500 pounds of phosphorus, and 3,900

pounds of potassium. This shows in the surface 6⅔ inches of an acre nearly five times as much nitrogen as the brown silt loam prairie. In phosphorus content these two soil types are about equal, but the peat contains less than one-tenth as much potassium as the brown silt loam. Thus the total supply of potassium in the peat to a depth of 7 inches (3,900 pounds) would be equivalent to the potassium requirement (73 pounds) of a hundred-bushel crop of corn for only 53 years; or if the equivalent of only one-fourth of one percent of this is annually available, in accordance with the rough estimate suggested in Bulletin 123, then about 10 pounds of potassium would be liberated annually, or sufficient for about 14 bushels of corn per acre.

In Table 14 are given all results obtained from the Manito (Mason county) experiment field on deep peat, which was begun in 1902 and discontinued after 1905. The plots in this field were one acre[1] each in size, 2 rods wide and 80 rods long. Untreated half-rod division strips were left between the plots, which, however, were cropped the same as the plots.

The results of four years' tests, as given in Table 14, are in complete harmony with the information furnished by the chemical composition of peat soil as compared with that of ordinary normal soils. Where potassium was applied, the yield was from three to four times as large as where nothing was applied. Where approximately equal money values of kainit and potassium chlorid were applied, slightly greater yields were obtained with the potassium chlorid, which, however, supplied about one third more potassium than the kainit. On the other hand, either material furnished more potassium than was required by the crops produced.

The use of 700 pounds of sodium chlorid (common salt) produced no appreciable increase over the best untreated plots, indicating that where potassium is itself actually deficient, salts of other elements cannot take its place.

Applications of 2 tons per acre of ground limestone produced no increase in the corn crops, either when applied alone or in combination with kainit, either the first year or the second.

TABLE 14.—CORN YIELDS IN SOIL EXPERIMENTS, MANITO FIELD; TYPICAL DEEP PEAT SOIL (Bushels per acre)

Plot No.	Soil treatment for 1902	Corn 1902	Corn 1903	Soil treatment for 1904	Corn 1904	Corn 1905	Four crops
1	None	10.9	8.1	None	17.0	12.0	48.0
2	None	10.4	10.4	Limestone, 4000 lbs.	12.0	10.1	42.9
3	Kainit, 600 lbs.	30.4	32.4	Limestone, 4000 lbs. Kainit, 1200 lbs.	49.6	47.3	159.7
4	Kainit, 600 lbs. Acidulat'd bone, 350 lb.	30.3	33.3	Kainit, 1200 lbs. Steamed bone, 395 lbs.	53.5	47.6	164.7
5	Potassium chlorid, 200 lbs.	31.2	33.9	Potassium chlorid, 400 lbs.	48.5	52.7	166.3
6	Sodium chlorid, 700 lbs.	11.1	13.1	None	24.0	22.1	70.3
7	Sodium chlorid, 700 lbs.	13.3	14.5	Kainit, 1200 lbs.	44.5	47.3	
8	Kainit, 600 lbs.	36.8	37.7	Kainit, 600 lbs.	44.0	46.0	164.5
9	Kainit, 300 lbs.	26.4	25.1	Kainit, 300 lbs.	41.5	32.9	125.9
10	None	14.9[1]	14.9	None	26.0	13.6	69.4

[1]Estimated from 1903; no yield was taken in 1902 because of a misunderstanding.

[1]In 1904 the yields were taken from quarter acre plots because of severe insect injury on the other parts of the field.

Reducing the application of kainit from 600 to 300 pounds for each two-year period, reduced the yield of corn from 164.5 to 125.9 bushels. The two applications of 300 pounds of kainit (Plot 9) furnished 60 pounds of potassium for the four years, an amount sufficient for 84 bushels of corn (grain and stalks). Attention is called to the fact that this is practically the difference between the yield of Plot 9 (125.9 bushels) and the yield obtained from Plot 2 (42.9 bushels), the poorest untreated plot.

Medium Peat on Clay (1402)

Medium peat on clay occurs in low, swampy areas, where the peat has not developed to a greater thickness than 30 inches. The total area is 640 acres, equivalent to 1 square mile, or .21 percent of the area of the county.

The surface, 0 to 6⅔ inches, is a brown or black peat, the decomposition varying with cultivation and drainage.

The subsurface, from 6⅔ inches to the depth of the peat, is usually a brownish peat that has not undergone a great amount of decomposition. In the classification used by this station, medium peat extends from 12 to 30 inches in depth, and in most areas the subsurface is usually taken as extending to the silty, clayey, or sandy layer. This gives a large variation in the thickness of the subsurface, but it is sampled to a depth of 20 inches.

The subsoil in this type consists of a silty clay and almost invariably is of light drab or bluish color, owing to deoxidation of iron by organic acids.

The treatment advised for this type is the same as for deep peat (1401), but thoro trials should be made with potassium in advance of extensive use. Drainage is an easier matter because tile may usually be placed in the clay.

Medium Peat on Sand (1402.2)

Medium peat on sand is found only on the old beach of Lake Michigan north of Waukegan, and here in very limited areas large enough to map. The total area is 284 acres.

The surface soil, 0 to 6⅔ inches, is a brownish, somewhat decomposed peat mixed with more or less sand.

The subsurface extends to a depth of 12 to 20 inches, passing into a drab-colored sand that continues to an indefinite depth. Practically none of this is under cultivation, altho some of it is used for pasture. Potassium is the only material suggested for trial applications.

Shallow Peat on Clay (1403)

Shallow peat on clay occurs in small areas on the upland and is usually not very uniform. The total area is 371 acres.

The surface soil, 0 to 6⅔ inches, consists of a dark, peaty material mixed with more or less sand, silt, or clay. It varies from pure peat to a very black silt or clay loam. Very few of these areas are under cultivation, but are mostly in pasture. The tramping of cattle has produced hummocks, which vary in height from 4 to 12 inches. An illustration of these is shown in Plate 9.

The subsurface soil is usually a brown silt loam, changing into a drab or bluish color at 12 to 16 inches in depth.

The subsoil is of the mottled drabbish or yellowish color and usually contains some fragments of limestone. Alkali patches are of frequent occurrence.

The first requirement of this type is good drainage. Where the surface is deficient in potassium, deeper plowing will bring abundance of it from the subsurface to be incorporated with the plowed soil.

Peaty Loam (1410)

Peaty loam is found in small areas in the depressions on the high terrace of Lake Michigan in the northeast part of the county. There is also one larger area in a broad valley west of Lake Bluff. The total area is not large, amounting to only 2.35 square miles, or .49 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, is a black, peaty loam. The amount of organic matter and sand varies in different areas, the organic matter varying from 10 to 25 percent or even more.

The subsurface soil is quite variable. In some areas it is a drabbish or bluish sand mixed with a variable amount of organic matter; in others it is a brown sandy loam; while in others it is clayey or silty.

The subsoil varies from a sand to a sand containing a considerable amount of silt and clay.

The first requirement of this type is good drainage. Some areas may require the application of potassium in order to produce well. This is true especially of those areas where the soil contains little or no clay. Alkali is frequently present in sufficient quantities to do great injury to crops, more particularly to

PLATE 9.—HUMMOCKS ON "BOG" LAND

corn. The alkali consists chiefly of harmless carbonate (limestone) with smaller amounts of injurious magnesium carbonate.

In some cases these peaty soils actually contain a good percentage of total potassium, more commonly in the subsurface or subsoil but sometimes in the surface soil also; and *yet* the untreated soil may be unproductive, while the addition of potassium salts may produce large and very profitable increases in the yield of corn, oats, etc. In pot-culture experiments we have even been able by the addition of potassium sulfate to correct to a considerable extent the injurious property of magnesium carbonate that has been purposely applied to ordinary brown silt loam prairie soil known to contain abundance of available potassium. These facts are mentioned here because the Experiment Station recommends, tentatively, the application of potassium salt to all classes of peaty and alkali soils that are unproductive after being well drained, whenever the supply of farm manure is insufficient. It should be understood that plenty of farm manure, preferably quick-acting, or readily decomposable, manure, such as horse manure, will supply potassium and thus accomplish everything that potassium salts can accomplish; on some swamp soils manure produces good results even where potassium is without effect.

Black Mixed Loam (1450)

Black mixed loam occurs in many of the low, swampy regions where organic matter has not accumulated sufficiently for the formation of peats. The morainal areas contain large numbers of small ponds, in which this type has developed, but they are too small to be shown on the map. The total area of this type is 19.72 square miles, 12,622 acres, or 4.09 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, varies from a peat to a black clay, black silt, or black sandy loam. The areas of these different phases are so small, however, and so badly mixed, that it is practically impossible to make any satisfactory separation of them into distinct types. For this reason the type is called black mixed loam. The content of organic matter varies from 6 to 20 percent.

The subsurface soil varies to a less extent than the surface. It is generally a dark silt or clay loam with some sand and gravel to a depth of 14 to 16 inches.

The subsoil varies from a drab to a yellow clayey silty material that is made up largely of boulder clay. Many limestone gravels are found in this stratum.

On the surface of this type are found many glacial boulders, mostly granites, that have either been left when the other material has been removed by water, or been brought to the surface by the action of frost. In many cases they are so numerous that cultivation would be impossible without removing them. They vary in size from a few inches to several feet in diameter.

In the management of this type, the first essential is thoro drainage. The variability of the soil makes it rather difficult to suggest any treatment that will apply to the type as a whole. It may be found that some areas will need applications of potassium. This is true of the small peaty areas as well as the alkali spots that are quite common in the type. Comparatively little of this type is under cultivation; nearly all of it is either in pasture or meadow.

The tramping of stock on this type produces hummocks, or "bogs," as they are frequently called by the farmers of this vicinity. The height of these may

be increased by freezing and thawing to 12 or 15 inches. Driving over such an area as this with implements is practically impossible. A "bog cutter," consisting of a series of either straight or curved knives, is used for reducing the hummocks before plowing. (See Plate 9.)

Mixed Loam (Bottom Land) (1454)

Mixed loam occurs along the streams. In many instances it is very much like the black mixed loam (1450); as a rule, however, it has received sufficient deposit from overflow to give it a more uniform character. The total area of this type is 8.51 square miles, 5,446 acres, or 1.76 percent of the area of the county.

The surface soil, 0 to 6⅔ inches, is brown to black in color, varying in texture from a silt loam to a sandy loam. The streams of this county overflow less than in other parts of the state because the numerous lakes act as reservoirs giving a steady flow. The lakes also act as silt basins, in which the sediment settles. For these reasons there is less sediment carried and deposited on the flood plains. The amount of organic matter varies from 5 to 10 percent with an average of 7.7 percent, or 77 tons per acre.

The subsurface soil, 6⅔ to 20 inches, varies from a brown silt loam to a brown sandy loam, and is a little lighter in color than the surface soil.

The subsoil varies from light brown to a yellowish or drabbish color, indicating that sufficient time has elapsed for the formation of a distinct subsoil. This occurs only where sedimentation takes place slowly.

Because of lack of drainage, comparatively little of this type is under cultivation. It makes good pasture land, and possibly that will be its principal use for years to come. Drainage is the first thing necessary. Where overflow occurs, high fertility is likely to be maintained.

Beach Sand (1482)

Beach sand, which might be called mixed sand and peat, extends from Waukegan to the state line and represents the beach of Lake Chicago. Its greatest width is about one mile. The area consists of a large number of sand ridges with peat deposits between them. These ridges are usually but a few rods wide, and still fewer rods apart, and the peat is represented by such small areas that it is practically impossible to indicate them on the map. The sand in some places has a covering of weeds, black oak, or stunted white pine. The soil is so variable here that it is practically impossible to give a description of the different strata, since in many cases a rod either way would mean an entire change of type. If drained, the treatment likely to be profitable will be suggested by a study of "dune sand" and "deep peat," described in the preceding pages.

LAKES

Lake county contains 47 lakes, having a total area of 18 square miles, 11,512 acres, or 3.72 percent of the entire area of the county. Many of these lakes have swampy shores, which fact indicates that a gradual extinction is going on and that in time they will be filled with organic deposits. Many of the peaty areas are without doubt extinct lakes that have been filled by the accumulation of organic matter.

APPENDIX

A study of the soil map and the tabular statements concerning crop requirements, the plant-food content of the different soil types, and the actual results secured from definite field trials with different methods or systems of soil improvement, and a careful study of the discussion of general principles and of the descriptions of individual soil types, will furnish the most necessary and useful information for the practical improvement and permanent preservation of the productive power of every kind of soil on every farm in the county.

More complete information concerning the most extensive and important soil types in the great soil areas in all parts of Illinois is contained in Bulletin 123, "The Fertility in Illinois Soils," which contains a colored general soil-survey map of the entire state.

Other publications of general interest are:

Bulletin No. 76, "Alfalfa on Illinois Soils"
Bulletin No. 94, "Nitrogen Bacteria and Legumes"
Bulletin No. 115, "Soil Improvement for the Worn Hill Lands of Illinois"
Bulletin No. 125, "Thirty Years of Crop Rotation on the Common Prairie Lands of Illinois"
Circular No. 82, "Physical Improvement of Soils"
Circular No. 110, "Ground Limestone for Acid Soils"
Circular No. 127, "Shall We Use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils?"
Circular No. 129, "The Use of Commercial Fertilizers"
Circular No. 149, "Results of Scientific Soil Treatment" and "Methods and Results of Ten Years' Soil Investigation in Illinois"
Circular No. 165, "Shall We Use 'Complete' Commercial Fertilizers in the Corn Belt?"
Circular No. 167, "The Illinois System of Permanent Fertility"

NOTE.—Information as to where to obtain limestone, phosphate, bone meal, and potassium salts, methods of application, etc., will also be found in Circulars 110 and 165.

SOIL SURVEY METHODS

The detail soil survey of a county consists essentially of ascertaining, and indicating on a map, the location and extent of the different soil types; and, since the value of the survey depends upon its accuracy, every reasonable means is employed to make it trustworthy. To accomplish this object three things are essential: first, careful, well-trained men to do the work; second, an accurate base map upon which to show the results of the work; and, third, the means necessary to enable the men to place the soil-type boundaries, streams, etc., accurately upon the map.

The men selected for the work must be able to keep their location exactly and to recognize the different soil types, with their principal variations and limits, and they must show these upon the maps correctly. A definite system is employed in checking up this work. As an illustration, one soil expert will survey and map a strip 80 rods or 160 rods wide and any convenient length, while his associate will work independently on another strip adjoining this area, and, if the work is correctly done, the soil type boundaries must match up on the line between the two strips.

An accurate base map for field use is absolutely necessary for soil mapping. The base maps are made on a scale of one inch to the mile. The official data of the original or subsequent land survey are used as a basis in the construction of these maps, while the most trustworthy county map available is used in

locating temporarily the streams, roads, and railroads. Since the best of these published maps have some inaccuracies, the location of every road, stream, and railroad must be verified by the soil surveyors, and corrected if wrongly located. In order to make these verifications and corrections, each survey party is provided with an odometer for measuring distances, and a plane table for determining directions of angling roads, railroads, etc.

Each surveyor is provided with a base map of the proper scale, which is carried with him in the field; and the soil type boundaries, ditches, streams, and necessary corrections are placed in their proper locations upon the map while the mapper is on the area. Each section, or square mile, is divided into 40-acre plots on the map, and the surveyor must inspect every ten acres and determine the type or types of soil composing it. The different types are indicated on the map by different colors, pencils for this purpose being carried in the field.

A small auger 40 inches long forms for each man an invaluable tool with which he can quickly secure samples of the different strata for inspection. An extension for making the auger 80 inches long is carried by each party, so that any peculiarity of the deeper subsoil layers may be studied. Each man carries a compass to aid in keeping directions. Distances along roads are measured by an odometer attached to the axle of the vehicle, while distances in the field off the roads are determined by pacing, an art in which the men become expert by practice. The soil boundaries can thus be located with as high a degree of accuracy as can be indicated by pencil on the scale of one inch to the mile.

SOIL CHARACTERISTICS

The unit in the soil survey is the soil type, and each type possesses more or less definite characteristics. The line of separation between adjoining types is usually distinct, but sometimes one type grades into another so gradually that it is very difficult to draw the line between them. In such exceptional cases, some slight variation in the location of soil-type boundaries is unavoidable.

Several factors must be taken into account in establishing soil types. These are (1) the geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial, or cumulose; (2) the topography, or lay of the land; (3) the native vegetation, as forest or prairie grasses; (4) the structure, or the depth and character of the surface, subsurface, and subsoil; (5) the physical, or mechanical, composition of the different strata composing the soil, as the percentages of gravel, sand, silt, clay, and organic matter which they contain; (6) the texture, or porosity, granulation, friability, plasticity, etc.; (7) the color of the strata; (8) the natural drainage; (9) the agricultural value, based upon its natural productiveness; (10) the ultimate chemical composition and reaction.

The common soil constituents are indicated in the following outline:

Soil constituents	Organic matter	Comprising undecomposed and partially decayed vegetable or organic material	
	Inorganic matter	Clay	.001 mm.[1] and less
		Silt	.001 mm. to .03 mm.
		Sands	.03 mm. to 1. mm.
		Gravel	1. mm. to 32 mm.
		Stones	32. mm. and over

Further discussion of these constituents is given in Circular 82.

[1]25 millimeters equal 1 inch.

GROUPS OF SOIL TYPES

The following gives the different general groups of soils:

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or silt.

Peaty loams—15 to 35 percent of organic matter mixed with much sand. Some silt and a little clay may be present.

Mucks—15 to 35 percent of partly decomposed organic matter mixed with much clay and silt.

Clays—Soils with more than 25 percent of clay, usually mixed with much silt.

Clay loams—Soils with from 15 to 25 percent of clay, usually mixed with much silt and some sand.

Silt loams—Soils with more than 50 percent of silt and less than 15 percent of clay, mixed with some sand.

Loams—Soils with from 30 to 50 percent of sand mixed with much silt and a little clay.

Sandy loams—Soils with from 50 to 75 percent of sand.

Fine sandy loams—Soils with from 50 to 75 percent of fine sand mixed with much silt and little clay.

Sands—Soils with more than 75 percent of sand.

Gravelly loams—Soils with 25 to 50 percent of gravel with much sand and some silt.

Gravels—Soils with more than 50 percent of gravel and much sand.

Stony loams—Soils containing a considerable number of stones over one inch in diameter.

Rock outcrop—Usually ledges of rock having no direct agricultural value.

More or less organic matter is found in all the above groups.

SUPPLY AND LIBERATION OF PLANT FOOD

The productive capacity of land in humid sections depends almost wholly upon the power of the soil to feed the crop; and this, in turn, depends both upon the stock of plant food contained in the soil and upon the rate at which it is liberated, or rendered soluble and available for use in plant growth. Protection from weeds, insects, and fungous diseases, tho exceedingly important, is not a positive but a negative factor in crop production.

The chemical analysis of the soil gives the invoice of fertility actually present in the soil strata sampled and analyzed, but the rate of liberation is governed by many factors, some of which may be controlled by the farmer, while others are largely beyond his control. Chief among the important controllable factors which influence the liberation of plant food are limestone and decaying organic matter, which may be added to the soil by direct application of ground limestone and farm manure. Organic matter may be supplied also by green-manure crops and crop residues, such as clover, cowpeas, straw, and corn stalks. The rate of decay of organic matter depends largely upon its age and origin,

and it may be hastened by tillage. The chemical analysis shows correctly the total organic carbon, which represents, as a rule, but little more than half the organic matter; so that 20,000 pounds of organic carbon in the plowed soil of an acre correspond to nearly 20 tons of organic matter. But this organic matter consists largely of the old organic residues that have accumulated during the past centuries because they were resistant to decay, and 2 tons of clover or cowpeas plowed under may have greater power to liberate plant food than the 20 tons of old, inactive organic matter. The recent history of the individual farm or field must be depended upon for information concerning recent additions of active organic matter, whether in applications of farm manure, in legume crops, or in grass-root sods of old pastures.

Probably no agricultural fact is more generally known by farmers and landowners than that soils differ in productive power. Even tho plowed alike and at the same time, prepared the same way, planted the same day with the same kind of seed, and cultivated alike, watered by the same rains and warmed by the same sun, nevertheless the best acre may produce twice as large a crop as the poorest acre on the same farm, if not, indeed, in the same field; and the fact should be repeated and emphasized that with the normal rainfall of Illinois the productive power of the land depends primarily upon the stock of plant food contained in the soil and upon the rate at which it is liberated, just as the success of the merchant depends primarily upon his stock of goods and the rapidity of sales. In both cases the stock of any commodity must be increased or renewed whenever the supply of such commodity becomes so depleted as to limit the success of the business, whether on the farm or in the store.

As the organic matter decays, certain decomposition products are formed, including much carbonic acid, some nitric acid, and various organic acids, and these have power to act upon the soil and dissolve the essential mineral plant foods, thus furnishing soluble phosphates, nitrates, and other salts of potassium, magnesium, calcium, etc., for the use of the growing crop.

As already explained, fresh organic matter decomposes much more rapidly than old humus, which represents the organic residues most resistant to decay and which consequently has accumulated in the soil during the past centuries. The decay of this old humus can be hastened both by tillage, which maintains a porous condition and thus permits the oxygen of the air to enter the soil more freely and to effect the more rapid oxidation of the organic matter, and also by incorporating with the old, resistant residues some fresh organic matter, such as farm manure, clover roots, etc., which decay rapidly and thus furnish or liberate organic matter and inorganic food for bacteria, the bacteria, under such favorable conditions, appearing to have power to attack and decompose the old humus. It is probably for this reason that peat, a very inactive and inefficient fertilizer when used by itself, becomes much more effective when composted with fresh farm manure; so that two tons of the compost[1] may be worth as much as two tons of manure, but if applied separately, the peat has little value. Bacterial action is also promoted by the presence of limestone.

[1]In his book, "Fertilizers," published in 1839, Cuthbert W. Johnson reported such compost to have been much used in England and to be valued as highly, "weight for weight, as farm-yard dung."

The condition of the organic matter of the soil is indicated more or less definitely by the ratio of carbon to nitrogen. As an average, the fresh organic matter incorporated with soils contains about twenty times as much carbon as nitrogen, but the carbohydrates ferment and decompose much more rapidly than the nitrogenous matter; and the old resistant organic residues, such as are found in normal subsoils, commonly contain only five or six times as much carbon as nitrogen. Soils of normal physical composition, such as loam, clay loam, silt loam, and fine sandy loam, when in good productive condition, contain about twelve to fourteen times as much carbon as nitrogen in the surface soil; while in old, worn soils that are greatly in need of fresh, active, organic manures, the ratio is narrower, sometimes falling below ten of carbon to one of nitrogen. Soils of cut-over or burnt over timber lands sometimes contain so much partially decayed wood or charcoal as to destroy the value of the nitrogen-carbon ratio for the purpose indicated. (Except in newly made alluvial soils, the ratio is usually narrower in the subsurface and subsoil than in the surface stratum.)

It should be kept in mind that crops are not made out of nothing. They are composed of ten different elements of plant food, every one of which is absolutely essential for the growth and formation of every agricultural plant. Of these ten elements of plant food, only two (carbon and oxygen) are secured from the air by all agricultural plants, only one (hydrogen) from water, and seven from the soil. Nitrogen, one of these seven elements secured from the soil by all plants, may also be secured from the air by one class of plants (legumes), in case the amount liberated from the soil is insufficient; but even these plants (which include only the clovers, peas, beans, and vetches, among our common agricultural plants) secure from the soil alone six elements (phosphorus, potassium, magnesium, calcium, iron, and sulfur), and also utilize the soil nitrogen so far as it becomes soluble and available during their period of growth.

Plants are made of plant-food elements in just the same sense that a building is made of wood and iron, brick, stone, and mortar. Without materials, nothing material can be made. The normal temperature, sunshine, rainfall, and length of season in central Illinois are sufficient to produce 50 bushels of wheat per acre, 100 bushels of corn, 100 bushels of oats, and 4 tons of clover hay; and, where the land is properly drained and properly tilled, such crops would frequently be secured *if the plant foods were present in sufficient amounts and liberated at a sufficiently rapid rate to meet the absolute needs of the crops.*

CROP REQUIREMENTS

The accompanying table shows the requirements of wheat, corn, oats, and clover for the five most important plant-food elements which the soil must furnish. (Iron and sulfur are supplied normally in sufficient abundance compared with the amounts needed by plants, so that they are never known to limit the yield of general farm crops grown under normal conditions.)

TABLE A.—PLANT FOOD IN WHEAT, CORN, OATS, AND CLOVER

Produce: Kind	Produce: Amount	Nitrogen	Phosphorus	Potassium	Magnesium	Calcium
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*
Wheat, grain.......	50 bu.	71	12	13	4	1
Wheat straw.......	2½ tons	25	4	45	4	10
Corn, grain..........	100 bu.	100	17	19	7	1
Corn stover.........	3 tons	48	6	52	10	21
Corn cobs..........	½ ton	2		2		
Oats, grain..........	100 bu.	66	11	16	4	2
Oat straw..........	2½ tons	31	5	52	7	15
Clover seed.........	4 bu.	7	2	3	1	1
Clover hay.........	4 tons	160	20	120	31	117
Total in grain and seed..................		244[1]	42	51	16	4
Total in four crops......................		510[1]	77	322	68	168

[1]These amounts include the nitrogen contained in the clover seed or hay, which, however, may be secured from the air.

To be sure, these are large yields, but shall we try to make possible the production of yields only half or a quarter as large as these, or shall we set as our ideal this higher mark, and then approach it as nearly as possible with profit? Among the four crops, corn is the largest, with a total yield of more than six tons per acre; and yet the 100-bushel crop of corn is often produced on rich pieces of land in good seasons. In very practical and profitable systems of farming, the Illinois Experiment Station has produced, as an average of the six years 1905 to 1910, a yield of 87 bushels of corn per acre in grain farming (with limestone and phosphorus applied, and with crop residues and legume crops turned under), and 90 bushels per acre in live-stock farming (with limestone, phosphorus, and manure).

The importance of maintaining a rich surface soil cannot be too strongly emphasized. This is well illustrated by data from the Rothamsted Experiment Station, the oldest in the world. On Broadbalk field, where wheat has been grown since 1844, the average yields for the ten years 1892 to 1901 were 12.3 bushels per acre on Plot 3 (unfertilized) and 31.8 bushels on Plot 7 (well fertilized), but the amounts of both nitrogen and phosphorus in the subsoil (9 to 27 inches) were distinctly greater in Plot 3 than in Plot 7, thus showing that the higher yields from Plot 7 were due to the fact that the plowed soil had been enriched. In 1893 Plot 7 contained per acre in the surface soil (0 to 9 inches) about 600 pounds more nitrogen and 900 pounds more phosphorus than Plot 3. Even a rich subsoil has little value if it lies beneath a worn-out surface.

METHODS OF LIBERATING PLANT FOOD

Limestone and decaying organic matter are the principal materials which the farmer can utilize most profitably to bring about the liberation of plant food. The limestone corrects the acidity of the soil and thus encourages the development not only of the nitrogen-gathering bacteria which live in the nodules on the roots of clover, cowpeas, and other legumes, but also the nitrifying bacteria, which have power to transform the insoluble and unavailable organic

nitrogen into soluble and available nitrate nitrogen. At the same time, the products of this decomposition have power to dissolve the minerals contained in the soil, such as potassium and magnesium, and also to dissolve the insoluble phosphate and limestone which may be applied in low-priced forms.

Tillage, or cultivation, also hastens the liberation of plant food by permitting the air to enter the soil and burn out the organic matter; but it should never be forgotten that tillage is wholly destructive, that it adds nothing whatever to the soil, but always leaves it poorer. Tillage should be practiced so far as is necessary to prepare a suitable seed bed for root development and also for the purpose of killing weeds, but more than this is unnecessary and unprofitable in seasons of normal rainfall; and it is much better actually to enrich the soil by proper applications or additions, including limestone and organic matter (both of which have power to improve the physical condition as well as to liberate plant food) than merely to hasten soil depletion by means of excessive cultivation.

Permanent Soil Improvement

The best and most profitable methods for the permanent improvement of the common soils of Illinois are as follows:

(1) If the soil is acid, apply at least two tons per acre of ground limestone, preferably at times magnesian limestone ($CaCO_3MgCO_3$), which contains both calcium and magnesium and has slightly greater power to correct soil acidity, ton for ton, than the ordinary calcium limestone ($CaCO_3$); and continue to apply about two tons per acre of ground limestone every four or five years. On strongly acid soils, or on land being prepared for alfalfa, five tons per acre of ground limestone may well be used for the first application.

(2) Adopt a good rotation of crops, including a liberal use of legumes, and increase the organic matter of the soil either by plowing under the legume crops and other crop residues (straw and corn stalks), or by using for feed and bedding practically all the crops raised and returning the manure to the land with the least possible loss. No one can say in advance what will prove to be the best rotation of crops, because of variation in farms and farmers, and in prices for produce, but the following are suggested to serve as models or outlines:

First year, corn.
Second year, corn.
Third year, wheat or oats (with clover or clover and grass).
Fourth year, clover or clover and grass.
Fifth year, wheat and clover or grass and clover.
Sixth year, clover or clover and grass.

Of course there should be as many fields as there are years in the rotation. In grain farming, with small grain grown the third and fifth years, most of the coarse products should be returned to the soil, and the clover may be clipped and left on the land (only the clover seed being sold the fourth and sixth years); or, in live-stock farming, the field may be used three years for timothy and clover pasture and meadow if desired. The system may be reduced to a five-year rotation by cutting out either the second or the sixth year, and to a four-year system by omitting the fifth and sixth years.

With two years of corn, followed by oats with clover-seeding the third year, and by clover the fourth year, all produce can be used for feed and bedding if other land is available for permanent pasture. Alfalfa may be grown on a fifth field for four or eight years, which is to be alternated with one of the four; or the alfalfa may be moved every five years, and thus rotated over all five fields every twenty-five years.

Other four-year rotations more suitable for grain farming are:

Wheat (and clover), corn, oats, and clover; or corn (and clover), cowpeas, wheat, and clover. (Alfalfa may be grown on a fifth field and rotated every five years, the hay being sold.)

Good three-year rotations are:

Corn, oats, and clover; corn, wheat, and clover; or wheat (and clover), corn (and clover), and cowpeas, in which two cover crops and one regular crop of legumes are grown in three years.

A five-year rotation of (1) corn (and clover), (2) cowpeas, (3) wheat, (4) clover, and (5) wheat (and clover) allows legumes to be seeded four times. Alfalfa may be grown on a sixth field for five or six years in the combination rotation, alternating between two fields every five years, or rotating over all the fields if moved every six years.

To avoid clover sickness it may sometimes be necessary to substitute sweet clover or alsike for red clover in about every third rotation, and at the same time to discontinue its use in the cover-crop mixture. If the corn crop is not too rank, cowpeas or soybeans may also be used as a cover crop (seeded at the last cultivation) in the southern part of the state, and, if necessary to avoid disease, these may well alternate in successive rotations.

For easy figuring it may well be kept in mind that the following amounts of nitrogen are required for the produce named:

1 bushel of oats (grain and straw) requires 1 pound of nitrogen.
1 bushel of corn (grain and stalks) requires 1½ pounds of nitrogen.
1 bushel of wheat (grain and straw) requires 2 pounds of nitrogen.
1 ton of timothy requires 24 pounds of nitrogen.
1 ton of clover contains 40 pounds of nitrogen.
1 ton of cowpeas contains 43 pounds of nitrogen.
1 ton of average manure contains 10 pounds of nitrogen.

The roots of clover contain about half as much nitrogen as the tops, and the roots of cowpeas contain about one tenth as much as the tops.

Soils of moderate productive power will furnish as much nitrogen to clover (and two or three times as much to cowpeas) as will be left in the roots and stubble. In grain crops, such as wheat, corn, and oats, about two-thirds of the nitrogen is contained in the grain and one-third in the straw or stalks. (See also discussion of "The Potassium Problem," on pages following.)

(3) On all lands deficient in phosphorus (except on those susceptible to serious erosion by surface washing or gullying) apply that element in considerably larger amounts than are required to meet the actual needs of the crops desired to be produced. The abundant information thus far secured shows positively that fine-ground natural rock phosphate can be used successfully and very profitably, and clearly indicates that this material will be the most economical form of phosphorus to use in all ordinary systems of permanent, profitable soil

improvement. The first application may well be one ton per acre, and subsequently about one-half ton per acre every four or five years should be applied, at least until the phosphorus content of the plowed soil reaches 2,000 pounds per acre, which may require a total application of from three to five or six tons per acre of raw phosphate containing 12½ percent of the element phosphorus.

Steamed bone meal and even acid phosphate may be used in emergencies, but it should always be kept in mind that phosphorus delivered in Illinois costs about 3 cents a pound in raw phosphate (direct from the mine in carload lots), but 10 cents a pound in steamed bone meal, and about 12 cents a pound in acid phosphate, both of which cost too much per ton to permit their common purchase by farmers in carload lots, which is not the case with limestone or raw phosphate.

Phosphorus once applied to the soil remains in it until removed in crops, unless carried away mechanically by soil erosion. (The loss by leaching is only about 1½ pounds per acre per annum, so that more than 150 years would be required to leach away the phosphorus applied in one ton of raw phosphate.)

The phosphate and limestone may be applied at any time during the rotation, but a good method is to apply the limestone after plowing and work it into the surface soil in preparing the seed bed for wheat, oats, rye, or barley, where clover is to be seeded; while phosphate is best plowed under with farm manure, clover, or other green manures, which serve to liberate the phosphorus.

(4) Until the supply of decaying organic matter has been made adequate, on the poorer types of upland timber and gray prairie soils some temporary benefit may be derived from the use of a soluble salt or a mixture of salts, such as kainit, which contains both potassium and magnesium in soluble form and also some common salt (sodium chlorid). About 600 pounds per acre of kainit applied and turned under with the raw phosphate will help to dissolve the phosphorus as well as to furnish available potassium and magnesium, and for a few years such use of kainit may be profitable on lands deficient in organic matter, but the evidence thus far secured indicates that its use is not absolutely necessary and that it will not be profitable after adequate provision is made for supplying decaying organic matter, since this will necessitate returning to the soil the potassium contained in the crop residues from grain farming or the manure produced in live-stock farming, and will also provide for the liberating of potassium from the soil. (Where hay or straw is sold, manure should be bought.)

On soils which are subject to surface washing, including especially the yellow silt loam of the upland timber area, and to some extent the yellow-gray silt loam and other more rolling areas, the supply of minerals in the subsurface and subsoil (which gradually renew the surface soil) tends to provide for a low-grade system of permanent agriculture if some use is made of legume plants, as in long rotations with much pasture, because both the minerals and nitrogen are thus provided in some amount almost permanently; but where such lands are farmed under such a system, not more than two or three grain crops should be grown during a period of ten or twelve years, the land being kept in pasture most of the time; and where the soil is acid a liberal use of limestone, as top-dressings if necessary, and occasional reseeding with clovers will benefit both the pasture and indirectly the grain crops.

ADVANTAGE OF CROP ROTATION AND PERMANENT SYSTEMS

It should be noted that clover is not likely to be well infected with the clover bacteria during the first rotation on a given farm or field where it has not been grown before within recent years; but even a partial stand of clover the first time will probably provide a thousand times as many bacteria for the next clover crop as one could afford to apply in artificial inoculation, for a single root-tubercle may contain a million bacteria developed from one during the season's growth.

This is only one of several advantages of the second course of the rotation over the first course. Thus the mere practice of crop rotation is an advantage, especially in helping to rid the land of insects and foul grass and weeds. The clover crop is an advantage to subsequent crops because of its deep-rooting characteristic. The larger applications of organic manures (made possible by the larger crops) are a great advantage; and in systems of permanent soil improvement, such as are here advised and illustrated, more limestone and more phosphorus are provided than are needed for the meager or moderate crops produced during the first rotation, and consequently the crops in the second rotation have the advantage of such accumulated residues (well incorporated with the plowed soil) in addition to the regular applications made during the second rotation.

This means that these systems tend positively toward the making of richer lands. The ultimate analyses recorded in the tables give the absolute invoice of these Illinois soils. They show that most of them are positively deficient only in limestone, phosphorus, and nitrogenous organic matter; and the accumulated information from careful and long-continued investigations in different parts of the United States clearly establishes the fact that in general farming these essentials can be supplied with greatest economy and profit by the use of ground natural limestone, very finely ground natural rock phosphate, and legume crops to be plowed under directly or in farm manure. On normal soils no other applications are absolutely necessary, but, as already explained, the addition of some soluble salt in the beginning of a system of improvement on some of these soils produces temporary benefit, and if some inexpensive salt, such as kainit, is used, it may produce sufficient increase to more than pay the added cost.

THE POTASSIUM PROBLEM

As reported in Illinois Bulletin 123, where wheat has been grown every year for more than half a century at Rothamsted, England, exactly the same increase was produced (5.6 bushels per acre), as an average of the first 24 years, whether potassium, magnesium, or sodium was applied, the rate of application per annum being 200 pounds of potassium sulfate and molecular equivalents of magnesium sulfate and sodium sulfate. As an average of 60 years (1852 to 1911), the yield of wheat was 12.7 bushels on untreated land and 23.3 bushels where 86 pounds of nitrogen and 29 pounds of phosphorus per acre per annum were applied. As further additions, 85 pounds of potassium raised the yield to 31.3 bushels; 52 pounds of magnesium raised it to 29.2 bushels; and 50 pounds of sodium raised it to 29.5 bushels. Where potassium was applied, the wheat crop removed an-

nually an average of 40 pounds of that element in the grain and straw, or three times as much as would be removed in the grain only for such crops as are suggested in Table A. The Rothamsted soil contained an abundance of limestone, but no organic matter was provided except the little in the stubble and roots of the wheat plants.

On another field at Rothamsted the average yield of barley for 60 years (1852 to 1911) was 14.2 bushels on untreated land, 38.1 bushels where 43 pounds of nitrogen and 29 pounds of phosphorus were applied per acre per annum; while the further addition of 85 pounds of potassium, 19 pounds of magnesium, and 14 pounds of sodium (all in sulfates) raised the average yield to 41.5 bushels. Where only 70 pounds of sodium were applied in addition to the nitrogen and phosphorus, the average was 43.0 bushels. Thus, as an average of 60 years, the use of sodium produced 1.8 bushels less wheat and 1.5 bushels more barley than the use of potassium, with both grain and straw removed and no organic manures returned.

In recent years the effect of potassium is becoming much more marked than that of sodium or magnesium, on the wheat crop; but this must be expected to occur in time where no potassium is returned in straw or manure, and no provision made for liberating potassium from the supply still remaining in the soil. If the wheat straw, which contains more than three-fourths of the potassium removed in the wheat crop (see Table A), were returned to the soil, the necessity of purchasing potassium in a good system of farming on such land would be at least very remote, for the supply would be adequately maintained by the actual amount returned in the straw, together with the additional amount which would be liberated from the soil by the action of decomposition products.

While about half the potassium, nitrogen, and organic matter, and about one-fourth the phosphorus contained in manure is lost by three or four months' exposure in the ordinary pile in the barn yard, there is practically no loss if plenty of absorbent bedding is used on cement floors, and if the manure is hauled to the field and spread within a day or two after it is produced. Again, while in average live-stock farming the animals destroy two thirds of the organic matter and retain one-fourth of the nitrogen and phosphorus from the food they consume, they retain less than one-tenth of the potassium; so that the actual loss of potassium in the products sold from the farm, either in grain farming or in live-stock farming, is wholly negligible on land containing 25,000 pounds or more of potassium in the surface 6⅔ inches.

The removal of one inch of soil per century by surface washing (which is likely to occur wherever there is satisfactory surface drainage and frequent cultivation) will permanently maintain the potassium in grain farming by renewal from the subsoil, provided one-third of the potassium is removed by cropping before the soil is carried away.

From all these facts it will be seen that the potassium problem is not one of addition but of liberation; and the Rothamsted records show that for many years other soluble salts have practically the same power as potassium to increase crop yields in the absence of sufficient decaying organic matter. Whether this

action relates to supplying or liberating potassium for its own sake, or to the power of the soluble salt to increase the availability of phosphorus or other elements, is not known, but where much potassium is removed, as in the entire crops at Rothamsted, with no return of organic residues, probably the soluble salt functions in both ways.

As an average of 112 separate tests conducted in 1907, 1908, 1909, and 1910 on the Fairfield experiment field, an application of 200 pounds of potassium sulfate, containing 85 pounds of potassium and costing $5.10, increased the yield of corn by 9.3 bushels per acre; while 600 pounds of kainit, containing only 60 pounds of potassium and costing $4, gave an increase of 10.7 bushels. Thus, at 40 cents a bushel for corn, the kainit paid for itself; but these results, like those at Rothamsted, were secured where no adequate provision had been made for decaying organic matter.

Additional experiments at Fairfield included an equally complete test with potassium sulfate and kainit on land to which 8 tons per acre of farm manure were applied. As an average of 112 tests with each material, the 200 pounds of potassium sulfate increased the yield of corn by 1.7 bushels, while the 600 pounds of kainit also gave an increase of 1.7 bushels. Thus, where organic manure was supplied, very little effect was produced by the addition of either potassium sulfate or kainit; in part perhaps because the potassium removed in the crops is mostly returned in the manure if properly cared for, and perhaps in larger part because the decaying organic matter helps to liberate and hold in solution other plant-food elements, especially phosphorus.

In laboratory experiments at the Illinois Experiment Station, it has been shown by chemical analysis that potassium salts and most other soluble salts increase the solubility of the phosphorus in soil and in rock phosphate; also that the addition of glucose with rock phosphate in pot-culture experiments increases the availability of the phosphorus, as measured by plant growth, altho the glucose consists only of carbon, hydrogen, and oxygen, and thus contains no plant food of value.

If we remember that, as an average, live stock destroy two thirds of the organic matter of the food they consume, it it easy to determine from Table A that more organic matter will be supplied in a proper grain system than in a strictly live-stock system; and the evidence thus far secured from older experiments at the University and at other places in the state indicates that if the corn stalks, straw, clover, etc., are incorporated with the soil as soon as practicable after they are produced (which can usually be done in the late fall or early spring), there is little or no difficulty in securing sufficient decomposition in our humid climate to avoid serious interference with the capillary movement of the soil moisture, a common danger from plowing under too much coarse manure of any kind in the late spring of a dry year.

If, however, the entire produce of the land is sold from the farm, as in hay farming or when both grain and straw are sold, of course the draft on potassium will then be so great that in time it must be renewed by some sort of application. As a rule, farmers following this practice ought to secure manure from town, since they furnish the bulk of the material out of which manure is produced.

Calcium and Magnesium

When measured by the actual crop requirements for plant food, magnesium and calcium are more limited in some Illinois soils than potassium. But with these elements we must also consider the loss by leaching. As an average of 90 analyses[1] of Illinois well-waters drawn chiefly from glacial sands, gravels, or till, 3 million pounds of water (about the average annual drainage per acre for Illinois) contained 11 pounds of potassium, 130 of magnesium, and 330 of calcium. These figures are very significant, and it may be stated that if the plowed soil is well supplied with the carbonates of magnesium and calcium, then a very considerable proportion of these amounts will be leached from that stratum. Thus the loss of calcium from the plowed soil of an acre at Rothamsted, England, where the soil contains plenty of limestone, has averaged more than 300 pounds a year as determined by analyzing the soil in 1865 and again in 1905. Practically the same amount of calcium was found, by analyses, in the Rothamsted drainage waters.

Common limestone, which is calcium carbonate ($CaCO_3$), contains, when pure, 40 percent of calcium, so that 800 pounds of limestone are equivalent to 320 pounds of calcium. Where 10 tons per acre of ground limestone were applied at Edgewood, Illinois, the average annual loss during the next ten years amounted to 790 pounds per acre. The definite data from careful investigations seem to be ample to justify the conclusion that where limestone is needed at least 2 tons per acre should be applied every 4 or 5 years.

It is of interest to note that thirty crops of clover of four tons each would require 3,510 pounds of calcium, while the most common prairie land of southern Illinois contains only 3,420 pounds of total calcium in the plowed soil of an acre. (See Soil Report No. 1.) Thus limestone has a positive value on some soils for the plant food which it supplies, in addition to its value in correcting soil acidity and in improving the physical condition of the soil. Ordinary limestone (abundant in the southern and western parts of the state) contains nearly 800 pounds of calcium per ton; while a good grade of dolomitic limestone (the more common limestone of northern Illinois) contains about 400 pounds of calcium and 300 pounds of magnesium per ton. Both of these elements are furnished in readily available form in ground dolomitic limestone.

Physical Improvement of Soils

In the management of most soil types, one very important thing, aside from proper fertilization, tillage, and drainage, is to keep the soil in good physical condition, or good tilth. The constituent most important for this purpose is organic matter. Not only does it impart good tilth to the soil, but it prevents much loss by washing on rolling land, warms the soil by absorption of heat, retains moisture during drouth, furnishes nitrogen for the crop, aids in the liberation of mineral plant food, and prevents the soil from running together badly. This constituent must be supplied to the soil in every practical way, so that the amount may be maintained or even increased. It is being broken down during a large part of the year, and the nitrates produced are used for plant growth.

[1]Reported by Doctor Bartow and associates, of the Illinois State Water Survey.

This breaking down is necessary, but it is also quite necessary that the supply be maintained.

The physical effect of organic matter in the soil is to produce a granulation, or mellowness, very favorable for tillage and the development of plant roots. If continuous cropping takes place, accompanied with the removal of the corn stalks and straw, the amount of organic matter is gradually diminished and a condition of poor tilth will ultimately follow. In many cases this already limits the crop yields. The remedy is to increase the organic-matter content by plowing under crop residues, such as corn stalks, straw, and clover. Selling these products from the farm, burning them, or feeding them and not returning the manure, or allowing a very large part of the manure to be lost before it is returned to the land, all represent bad practice.

One of the chief sources of loss of organic matter in the corn belt is the practice of burning the corn stalks. Could the farmers be made to realize how great a loss this entails, they would certainly discontinue the practice. Probably no form of organic matter acts more beneficially in producing good tilth than corn stalks. It is true that they decay rather slowly, but it is also true that their durability in the soil after partial decomposition is exactly what is needed in the maintenance of an adequate supply of humus.

The nitrogen in a ton of cornstalks is 1½ times that in a ton of manure, and a ton of dry corn stalks incorporated with the soil will ultimately furnish as much humus as 4 tons of average farm manure; but when burned, both the humus-making material and the nitrogen which these stalks contain are destroyed and lost to the soil.

The objection is often raised that when stalks are plowed under they interfere very seriously in the cultivation of corn, and thus indirectly destroy a great deal of corn. If corn stalks are well cut up and then turned under to a depth of 5½ to 6 inches when the ground is plowed in the spring, very little trouble will result.

Where corn follows corn, the stalks, if not needed for feeding purposes, should be thoroly cut up with a sharp disk or stalk cutter and turned under. Likewise, the straw should be returned to the land in some practical way, either directly or as manure. Clover should be one of the crops grown in the rotation, and it should be plowed under directly or as manure instead of being sold as hay, except when manure can be brought back.

It must be remembered, however, that in the feeding of hay, or straw, or corn stalks, a great destruction of organic matter takes place, so that even if the fresh manure were returned to the soil, there would still be a loss of 50 to 70 percent owing to the destruction of organic matter by the animal. If manure is allowed to lie in the farmyard for a few weeks or months, there is an additional loss which amounts to from one-third to two-thirds of the manure recovered from the animal. This is well shown by the results of an experiment conducted by the Maryland Experiment Station, where 80 tons of manure were allowed to lie for a year in the farmyard and at the end of that time but 27 tons remained, entailing a loss of about 66 percent of the manure. Most of this loss occurs within the first three or four months, when fermentation, or "heating," is most active. Two tons of manure were exposed from April 29 to August 29, by the

Canadian Experiment Station at Ottawa. During these four months the organic matter was reduced from 1,938 pounds to 655 pounds. To obtain the greatest value from the manure, it should be applied to the soil as soon as possible after it is produced.

It is a common practice in the corn belt to pasture the corn stalks during the winter and often rather late in the spring after the frost is out of the ground. This tramping of stock sometimes puts the soil in bad condition for working. It becomes partially puddled and will be cloddy as a result. If tramped too late in the spring, the natural agencies of freezing and thawing, and wetting and drying, with the aid of ordinary tillage, fail to produce good tilth before the crop is to be planted. Whether the crop is corn or oats, it necessarily suffers, and if the season is dry, much damage may result. If the field is put in corn, a poor stand is likely to follow, and if put in oats, a compact soil is formed which is unfavorable for their growth. Sometimes the soil is worked when too wet. This also produces a partial puddling which is unfavorable to physical, chemical, and biological processes. The bad effect will be greater if cropping has reduced the organic matter below the amount necessary to maintain good tilth.

PUBLICATIONS RELATING TO ILLINOIS SOIL INVESTIGATIONS

No. BULLETINS

76 Alfalfa on Illinois Soil, 1902 (5th edition, 1913).
*86 Climate of Illinois, 1903.
*88 Soil Treatment for Wheat in Rotation, with Special Reference to Southern Illinois, 1903.
*93 Soil Treatment for Peaty Swamp Lands, Including Reference to Sand and "Alkali" Soils, 1904. (See No. 157.)
94 Nitrogen Bacteria and Legumes, 1904 (4th edition, 1912).
*99 Soil Treatment for the Lower Illinois Glaciation, 1905.
115 Soil Improvement for the Worn Hill Lands of Illinois, 1907.
123 The Fertility in Illinois Soils, 1908 (2d edition, 1911).
*125 Thirty Years of Crop Rotations on the Common Prairie Soil of Illinois, 1908.
145 Quantitative Relationships of Carbon, Phosphorus, and Nitrogen in Soils, 1910 (2d edition, 1912).
157 Peaty Swamp Lands; Sand and "Alkali" Soils, 1912.
177 Radium as a Fertilizer, 1915.
181 Moisture and Tillage for Corn, 1915.

CIRCULARS

*64 Investigations of Illinois Soils, 1903.
*68 Methods of Maintaining the Productive Capacity of Illinois Soils, 1903 (2d edition, 1905).
*70 Infected Alfalfa Soil, 1903.
*72 Present Status of Soil Investigation, 1903 (2d edition, 1904).
82 The Physical Improvement of Soils, 1904 (3d edition, 1912).
86 Science and Sense in the Inoculation of Legumes, 1905 (2d edition, 1913).
*87 Factors in Crop Production, with Special Reference to Permanent Agriculture in Illinois, 1905.
*96 Soil Improvement for the Illinois Corn Belt, 1905 (2d edition, 1906).
*97 Soil Treatment for Wheat on the Poorer Lands of the Illinois Wheat Belt, 1905.
*99 The "Gist" of Four Years' Soil Investigations in the Illinois Wheat Belt, 1905.
*100 The "Gist" of Four Years' Soil Investigations in the Illinois Corn Belt, 1905.
105 The Duty of Chemistry to Agriculture, 1906 (2d edition, 1913).
108 Illinois Soils in Relation to Systems of Permanent Agriculture, 1907.
109 Improvement of Upland Timber Soils of Illinois, 1907.
110 Ground Limestone for Acid Soils, 1907 (3d edition, 1912).
*116 Phosphorous and Humus in Relation to Illinois Soils, 1908.
119 Washing of Soils and Methods of Prevention, 1908 (2d edition, 1912).
*122 Seven Years' Soil Investigation in Southern Illinois, 1908.
123 The Status of Soil Fertility Investigations, 1908.
124 Chemical Principles of Soil Fertility, 1908.
127 Shall We Use Natural Rock Phosphate or Manufactured Acid Phosphate for the Permanent Improvement of Illinois Soils? 1909 (3d edition, 1912).
*129 The Use of Commercial Fertilizers, 1909.
130 A Phosphate Problem for Illinois Land Owners, 1909.
*141 Crop Rotation for Illinois Soils, 1910 (2d edition, 1913).
142 European Practice and American Theory Concerning Soil Fertility, 1910.
145 The Story of a King and Queen, 1910.
149 Results of Scientific Soil Treatment; and Methods and Results of Ten Years' Soil Investigation in Illinois, 1911.
150 Collecting and Testing Soil Samples, 1911 (2d edition, 1912).
155 Plant Food in Relation to Soil Fertility, 1912.
157 Illinois Conditions, Needs, and Future Prospects, 1912.
165 Shall we Use "Complete" Commercial Fertilizers in the Corn Belt? 1912 (4th edition, 1913).
167 The Illinois System of Permanent Fertility, 1913.
168 Bread from Stones, 1913.
181 How Not to Treat Illinois Soils, 1915.

SOIL REPORTS

1 Clay County Soils, 1911.
2 Moultrie County Soils, 1911.
3 Hardin County Soils, 1912.
4 Sangamon County Soils, 1912.
5 La Salle County Soils, 1913.
6 Knox County Soils, 1913.
7 McDonough County Soils, 1913.
8 Bond County Soils, 1913.
9 Lake County Soils, 1915.

---

*Out of print.

THIRTEEN YEARS' RESULTS WITH PHOSPHORUS ON THE UNIVERSITY OF ILLINOIS SOIL EXPERIMENT FIELD AT BLOOMINGTON, ON THE TYPICAL PRAIRIE LAND OF THE ILLINOIS CORN BELT

Year	Crop grown	Yield without phosphorus	Yield with phosphorus	Increase for phosphorus	Value of increase per acre
1902	Corn, bu.	37.0	41.7	4.7	$ 1.64
1903	Corn, bu.	60.3	73.0	12.7	4.44
1904	Oats, bu.	60.8	72.7	11.9	3.33
1905	Wheat, bu.	28.8	39.2	10.4	7.28
1906	Clover, tons	.58	1.65	1.07	7.49
1907	Corn, bu.	63.1	82.1	19.0	6.65
1908	Corn, bu.	35.3	47.5	12.2	4.27
1909	Oats, bu.	53.6	63.8	10.2	2.86
1910	Clover, tons	1.09	4.21	3.12	21.85
1911	Wheat, bu.	22.5	57.6	35.1	24.58
1912	Corn, bu.	47.9	74.5	26.6	9.30
1913	Corn, bu.	30.0	44.1	14.1	4.93
1914	Oats, bu.	40.6	45.0	4.4	1.23

Total value of increase in thirteen years $99.85
Total cost of phosphorus in thirteen years 32.50

Net profit in thirteen years $67.35

After the first year the phosphorus began to more than pay its annual cost; and during the second five-year period the increase produced by the phosphorus was worth almost as much as the total crops produced on the land not receiving phosphorus. In later years the need of organic manures with phosphorus has become apparent. (See pages 17 to 22 for more complete details.)

Accessibility Statement

The Natural Resources Conservation Service (NRCS) is committed to making its information accessible to all of its customers and employees. If you are experiencing accessibility issues and need assistance, please contact our Helpdesk by phone at (800) 457-3642 or by e-mail at ServiceDesk-FTC@ftc.usda.gov. For assistance with publications that include maps, graphs, or similar forms of information, you may also wish to contact our State or local office. You can locate the correct office and phone number at http://offices.sc.egov.usda.gov/locator/app.

The USDA Target Center can convert USDA information and documents into alternative formats, including Braille, large print, video description, diskette, and audiotape. For more information, visit the TARGET Center's Web site (http://www.targetcenter.dm.usda.gov/) or call (202) 720-2600 (Voice/TTY).

Nondiscrimination Policy

The U.S. Department of Agriculture (USDA) prohibits discrimination against its customers, employees, and applicants for employment on the basis of race, color, national origin, age, disability, sex, gender identity, religion, reprisal, and where applicable, political beliefs, marital status, familial or parental status, sexual orientation, whether all or part of an individual's income is derived from any public assistance program, or protected genetic information. The Department prohibits discrimination in employment or in any program or activity conducted or funded by the Department. (Not all prohibited bases apply to all programs and/or employment activities.)

To File an Employment Complaint

If you wish to file an employment complaint, you must contact your agency's EEO Counselor (http://directives.sc.egov.usda.gov/33081.wba) within 45 days of the date of the alleged discriminatory act, event, or personnel action. Additional information can be found online at http://www.ascr.usda.gov/complaint_filing_file.html.

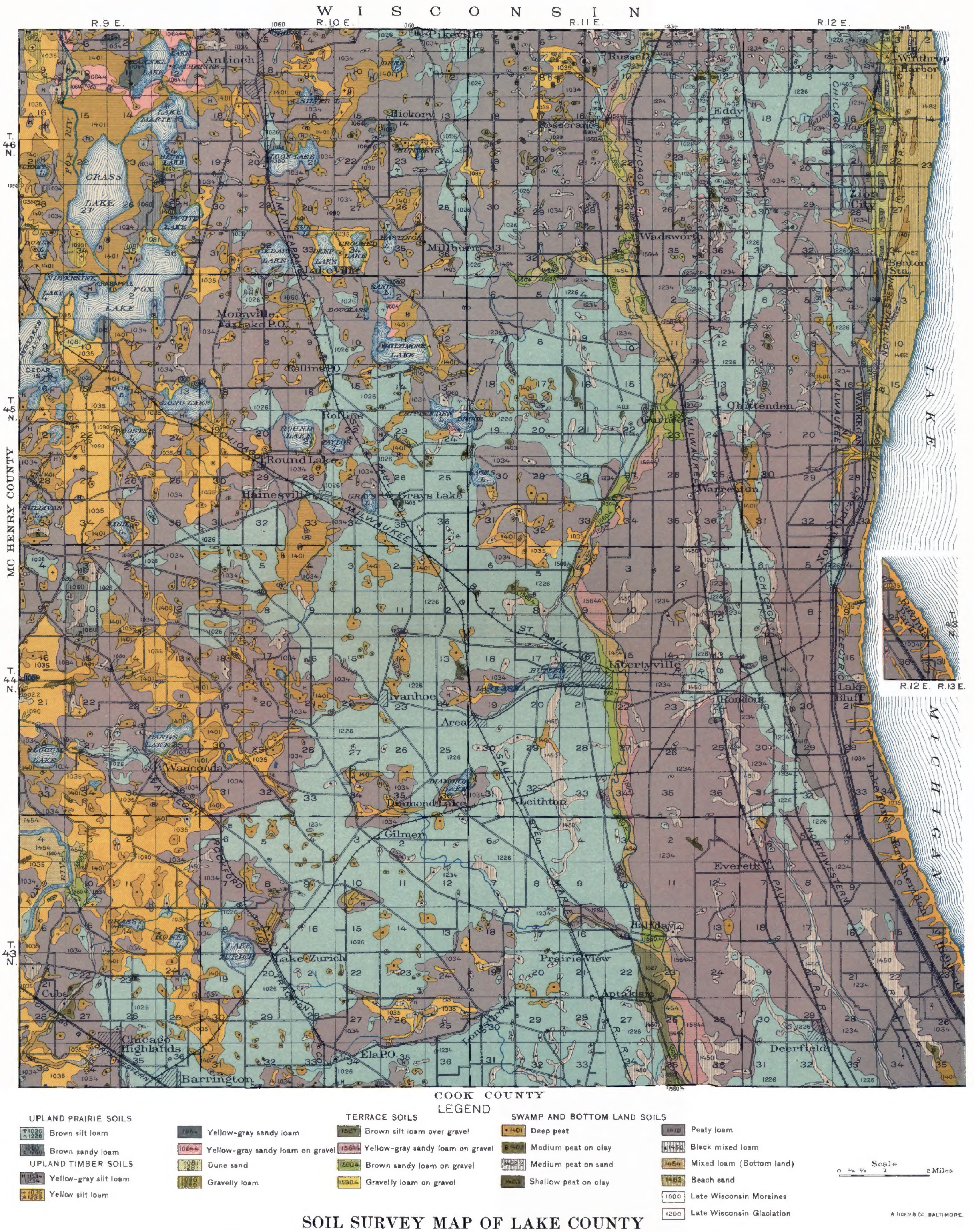
To File a Program Complaint

If you wish to file a Civil Rights program complaint of discrimination, complete the USDA Program Discrimination Complaint Form, found online at http://www.ascr.usda.gov/complaint_filing_cust.html or at any USDA office, or call (866) 632-9992 to request the form. You may also write a letter containing all of the information requested in the form. Send your completed complaint form or letter by mail to U.S. Department of Agriculture; Director, Office of Adjudication; 1400 Independence Avenue, S.W.; Washington, D.C. 20250-9419; by fax to (202) 690-7442; or by email to program.intake@usda.gov.

Persons with Disabilities

If you are deaf, are hard of hearing, or have speech disabilities and you wish to file either an EEO or program complaint, please contact USDA through the Federal Relay Service at (800) 877-8339 or (800) 845-6136 (in Spanish).

If you have other disabilities and wish to file a program complaint, please see the contact information above. If you require alternative means of communication for program information (e.g., Braille, large print, audiotape, etc.), please contact USDA's TARGET Center at (202) 720-2600 (voice and TDD).



SOIL SURVEY MAP OF LAKE COUNTY
UNIVERSITY OF ILLINOIS AGRICULTURAL EXPERIMENT STATION